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ANN ARBOR MICH

Rain Penetration of Brick Masonry . . 360
More Stable Gage Blocks 368
Identification of Fibers 381
Crack Propagation 389
Making the Electron Behave 394
64th Annual Meeting 395

$$\eta = \frac{\tau}{\dot{\gamma}}$$

NEWTON AND THE NON-CONFORMIST FLUIDS

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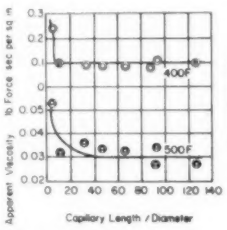
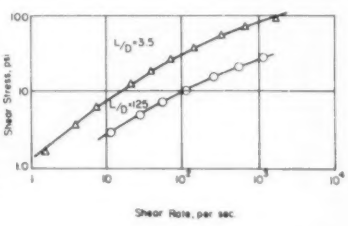


Effect of capillary L/D ratio upon apparent viscosity.



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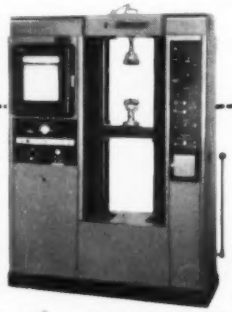

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TECHNICAL PAPERS

A Small-Panel Method for Investigating Moisture Penetration and Bond Strength of Brick Masonry—T. Ritchie 360
The Development of More Stable Gage Blocks—M. R. Meyerson, T. R. Young, and W. R. Ney 368
Compression Testing of Gypsum Plaster—E. H. Waters and R. Birtwistle 374
The Identification and Quantitative Determination of Natural and Manufactured Fibers—S. S. Praeger 381
Loss of Moisture from Fresh Mortars to Bricks—J. I. Davison 385

ARTICLES

The Slow Growth and Rapid Propagation of Cracks—Second Report of a Special ASTM Committee 389
ASTM Specifications in the Southern Standard Building Code—M. L. Clement 408

DEPARTMENTS

Actions on Standards	401	Material Questions	406
ASTM Meetings	405	Materials and Testing Topics	424
Bookshelf	414	Materials Sciences	404
Calendar	415	New ASTM Publications	401
Coming *MR&S* Papers	409	New Members	436
Comment	359	News of Members	418
Deaths	422	OTS Reports	434
Districts	404	Society Affairs	394
Index to Advertisers	439	Technical Committee Notes	398

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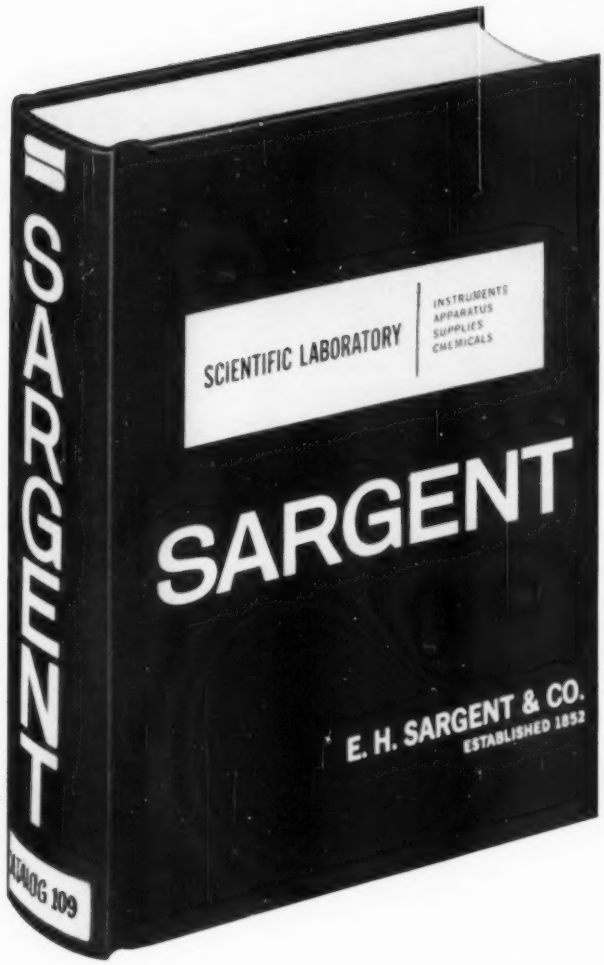

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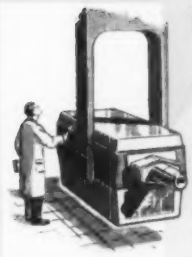

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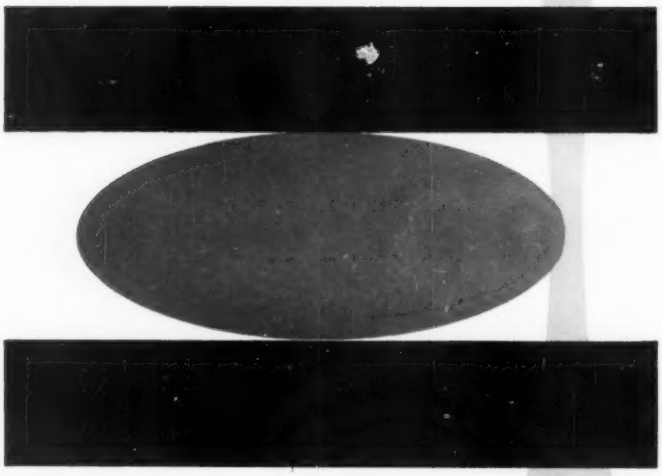

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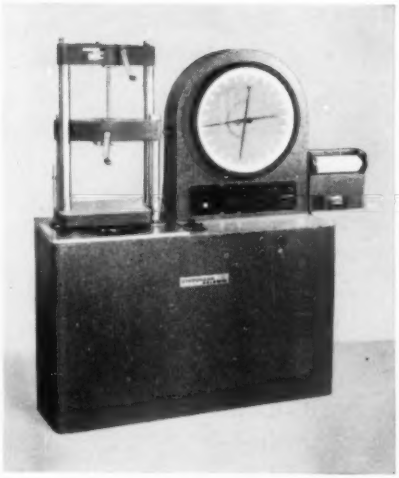

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In This Issue...

- **Rain penetration of brick masonry** has been studied using a small, economical test panel. The same type of panel has been used to study mortar bond strength 360

- **Higher precision and closer tolerances** are two of the demands being placed on American industry by the space age. Significant advances have been made recently at the National Bureau of Standards in developing highly stable gage blocks and ultraprecise measuring techniques. Here is a progress report on the NBS program 368

- **Compressive strength of gypsum plaster** is affected by many variables which scatter test results. These variables were studied and their effects on the results of compression tests are reported 374

- **Several new man-made fibers** appear on the textile market every year, adding to the almost bewildering abundance already available. This paper summarizes methods of qualitative and quantitative analysis for natural and man-made fibers 381

- **Tests of small brick panels** indicate a weaker bond between a mortar bed and the brick above than between the bed and the brick below. Loss of moisture from fresh mortars to bricks was studied in an effort to explain this difference 385

- **Slow Growth and Rapid Propagation of Cracks** is the title of this second report by the Special Committee on Fracture Testing of High-Strength Metallic Materials. This report aims to clarify some of the practical applications of fracture mechanics concepts 389

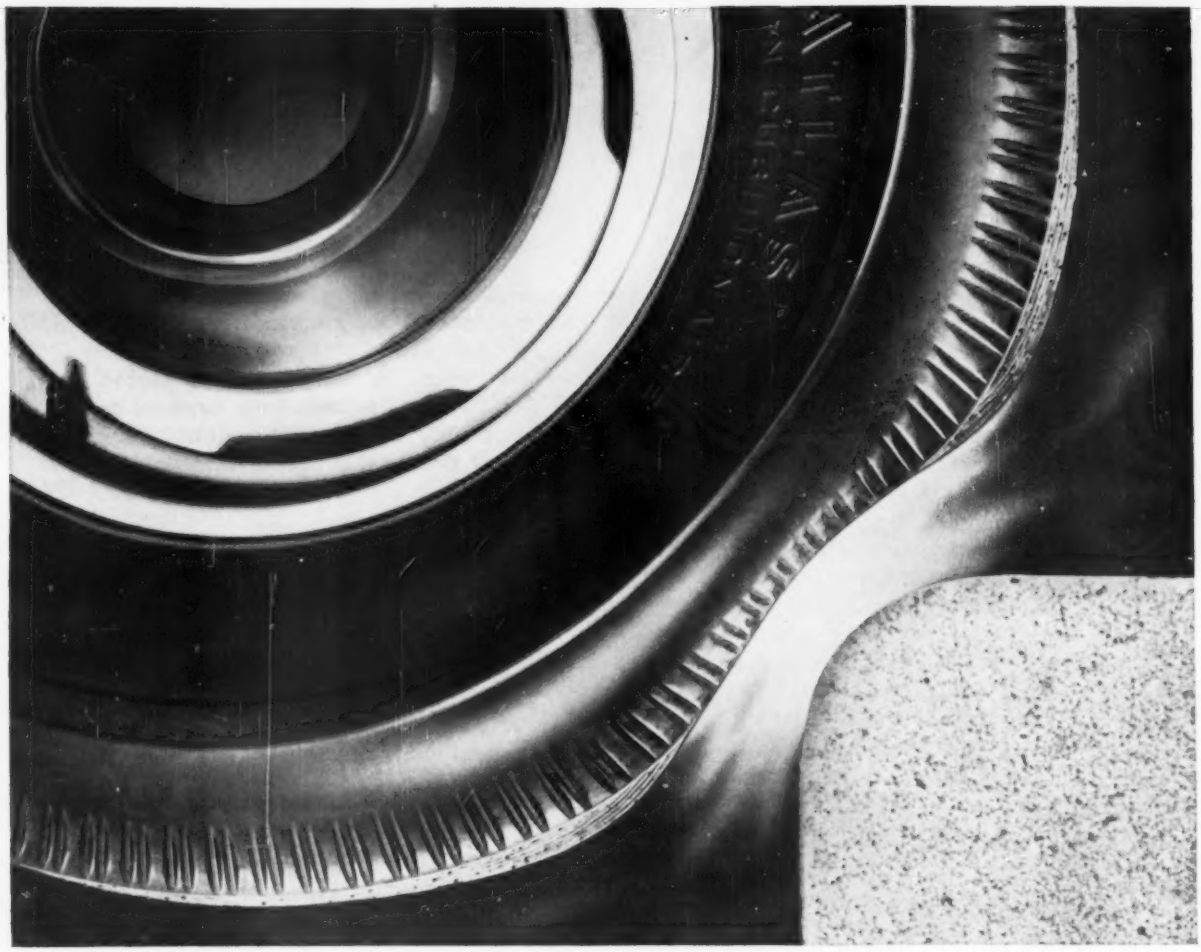
- **Symposium on Materials and Electron Device Processing** brings more than 300 registrants up to date on the latest techniques for making the electron behave 394

- **64th Annual Meeting of ASTM** shapes up to be another whopping week. Here is the word on the Marburg and Gillett Lectures, together with the last-minute program changes 395

- **Building Codes in the South** have come a long way in little more than a decade. ASTM standards have helped 408

COVER PHOTO:

Dust shields and "dry boxes" provide ultraclean, controlled environments for a transistor production line. Photo taken from "An Approach to Control of Transistor Process Environments," by C. A. Smith and T. Manns, Philco Corp., presented at the Symposium on Materials and Electron Device Processing. (See "Making the Electron Behave," p. 394)



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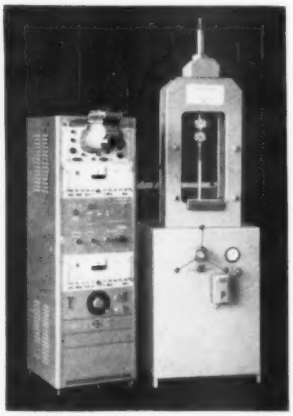

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Materials
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Volume 1, Number 5, May, 1961

COMMENT

ASTM Committee Work—A Postgraduate Education

To THE FLEDGLING engineer, just emerging from the cradle of the campus, the ink still wet on his diploma, the road ahead leads straight to a career in research, or in production, or sales, or management. If he has heard of ASTM at all, he may think of ASTM standards as a body of lifeless, static documents for which he may have occasional use from time to time, but in which he has, otherwise, little stake or interest. He may be unaware of the vital, dynamic character of materials standards and of the vast body of research that is being carried on every day by dedicated engineers who have taken upon themselves, through active membership in the Society, the responsibility for the continuing growth, validity, and usefulness of ASTM standards.

Unless someone changes his ideas, this newly graduated engineer may miss one of the finest opportunities open to him for future professional growth. Materials standards are alive: they are born, they grow, and, when their usefulness has passed, they die. ASTM committees are *working* committees. They create new standards, officiate at their birth, change them if they prove to be misshapen, breath new life into them when they weaken. To work with these committees is to benefit from a postgraduate education from which many things can be learned that cannot be learned in a classroom or even on the job.

ASTM committees are made up of men who are the recognized leaders in their fields. That these men are, indeed, at the forefront of their respective technologies is proved by the voice of authority with which ASTM standards speak throughout the world. The young engineer joining such a group has the opportunity to meet such men personally, to exchange views with them, to work with them on research projects in the field of materials.

Through his association with men of national reputation in his field, the committee member is able to broaden his outlook far beyond the confines of what goes on in his own company and can supplement what he learns from the technical literature in his field by personal contact with the men who produce that literature. He avoids the ever-present danger that he will be trapped, by day-to-day pressure of routine work assignments, into a cloistered view of his profession.

The committee member takes part in research projects bearing on the same problems he wrestles with in his own work—projects that are industry-wide in scope and importance. This keeps him up-to-date on the latest methods of research and analysis and the newest materials lore that will be useful to him on the job.

The give-and-take of committee work offers the young engineer an excellent place to sharpen his ability to work with others—to listen as well as to communicate his own ideas, to compromise where necessary, to judge the difference between those situations that indicate he should stick by his guns and those that indicate he should strike his colors. The development of such qualities as these are no less important to him than the purely technical ones. And in the committee, he has the chance to develop them in a democratic atmosphere untinged by the supervisor-employee-subordinate relationship.

Qualities of leadership can also be developed and exercised as the member gradually assumes positions of increasing responsibility and authority in the committee and in the Society. Technical committees, subcommittees, and task groups all need leaders who can point the way to accomplishment of assigned missions and can keep the group moving on the right road.

At one and the same time, then, work on an ASTM committee offers a path to maturity in the two areas that are vital to the success of any engineer—the technical and the administrative. In fact, from this relationship everyone benefits: the engineer benefits from his development as an individual, his company benefits from his increasing worth as an employee, the Society benefits from another strong hand pulling at the oar, and industry as a whole benefits from the production of modern, useful standards for materials.

A.Q.M.

A Small-Panel Method for Investigating Moisture Penetration and Bond Strength of Brick Masonry

By T. RITCHIE

Large bricklayer-constructed wallettes have been used by many laboratories in studies of the problem of moisture penetration of brick masonry. Although they reproduce actual conditions of construction of brick masonry, there are disadvantages to their use, such as cost, space requirements, and possible variation in workmanship or technique of bricklaying. A method for investigating factors in the problem of moisture penetration of brick masonry was developed which makes use of a small panel of bricks and mortar. The same panels used in moisture penetration tests can also be tested for strength of bond in direct tension between brick and mortar. The method of panel construction and the apparatus for tests of moisture penetration and bond strength are described.

RAIN penetration is a problem common to many unit masonry buildings in Canada and, for many years, has been studied by the Division of Building Research (DBR) of the National Research Council. Some of the factors involved in the problem have been investigated by DBR using a rain penetration apparatus similar to that developed by the U. S. National Bureau of Standards.[1] For these tests large masonry walls, about $3\frac{1}{2}$ ft wide and 4 ft high, are constructed by a bricklayer and tested for rain resistance by spraying water on the surface and applying an air-pressure difference across the wall to simulate heavy wind-driven rain. In studies at DBR using these large walls, certain disadvantages have been recognized. In addition to the expense of constructing and storing the several walls necessary to study the many factors involved in the problem of rain penetration, there is a workmanship factor which may introduce a variable difficult to control. Although studies are continuing on large walls, since they represent the practical conditions of construction, a small-panel method for investigating moisture penetration of masonry has been developed. The method has been used to study the influence of brick and mortar properties on moisture penetration, and also the influence of some factors connected with the bricklaying operation.

The small test panel is subjected to a rain test in the same way as the large panels; an air-pressure difference is maintained across the panel to simulate wind force, and at the same time water is sprayed on the surface to form a continuous film. The test conditions, therefore, represent heavy wind-driven rain. The length of time for moisture to pass through the panel and the subsequent rate of leakage of moisture through it are measured during the test.

A method of determining the strength of bond between brick and mortar has also been developed, employing the same type of panel used in the mositure penetration test. The bricks on either side of a mortar joint are clamped, and the clamps are pulled apart by a force normal to the mortar bed, causing failure of the bond in direct tension.

Test Panels

The procedure for assembling the panel was adapted from that developed by C. C. Fishburn[2] in preparing crossed-brick couplets for tests of bond strength between brick and mortar. In preparing the specimens a mold is placed over the bottom brick and a bed of mortar cast in it. The second brick is placed on the mortar and tapped by a dropping hammer. The two bricks are later pulled apart to determine the strength of adherence of mortar to brick.

The panels made in the DBR laboratory contain five bricks, laid one above the other with four horizontal mortar joints. Although panels could be made to contain vertical joints, this would complicate the method of building them.

Bricks

The bricks to be used in the panels are tested for the property of initial rate of absorption[3] and then dried thoroughly before they are built into the panel. Initial rate of absorption has an important influence on the bonding of mortar to bricks, and since this property may vary widely even within bricks from the same lot, those used in the construction of test panels are selected to be within a narrow range of initial rate of absorption.

Mortar

An individual batch of mortar is prepared for each of the four mortar joints in the panel. The water, cementing materials, and sand are mixed in a small Hobart mixer (type N-50); the amount of water is predetermined to produce a selected flow. Each mortar batch contains $\frac{1}{30}$ cu ft of sand, which is the volume obtained from the standard mold used in ASTM soil tests. The air-dried sand compacted in the mold is weighed, and this amount of sand is proportioned by weight for the mortar mixes. The volume of cementing material for the mix is calculated on the basis of $\frac{1}{30}$ cu ft of sand, usually in the ratio 1:3 by volume of cementing material to sand. The volume required is converted to weight, and the cementing material is proportioned by weight for the mix.

In preparing the mortar, the water is placed in the bowl first and then the cementing materials are added. The mixer is started simultaneously with a stopwatch to record the time of mixing.

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] C. C. Fishburn, D. Watstein, and D. C. Parsons, "Water Permeability of Masonry Walls," U. S. Department of Commerce, *Report B.M.S. 7*, 1938.

[2] C. C. Fishburn, information presented to ASTM Committee C-12 on Mortars for Unit Masonry, February, 1958.

[3] Methods of Sampling and Testing Brick, C 67-57, 1959 Book of ASTM Standards, Part 5, p. 59.

T. RITCHIE is an Associate Research Officer of the Division of Building Research of the National Research Council of Canada. He was graduated in ceramic engineering from the University of Toronto in 1949 and joined the Division of Building Research in 1950, where he has undertaken studies of problems relating to unit masonry construction. He is a member of ASTM Committee C-15 on Manufactured Masonry Units.

After the mixer starts, the sand is gradually added to the bowl so that it is all added in approximately the first 20 sec of mixing.

The first 2 min of mixing are at low speed, then the machine is stopped and mortar on the sides of the bowl is scraped down with a rubber scraper, taking about 10 sec. The machine is started again at medium speed and the mixing carried on for 50 sec. The total mixing time is 3 min, the first 2 min at low speed, and the last at medium speed. The mortar is allowed to stand in the bowl for 1 min after mixing and then is placed in a metal mold on the brick to form the joint.

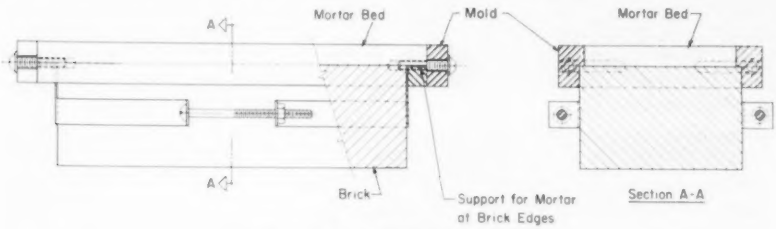

Fig. 1.—Mold for mortar joints.

Assembling the Panel

The mortar is placed in a mold made of steel bars which rise $\frac{1}{2}$ in. above the brick surface. Narrow shoulders on the side members rest on the brick, supporting the mold in place. The sides of the mold therefore are inset about $\frac{1}{8}$ in. from the faces of the brick. Before the brick is used in panel construction it is fitted with metal clips which extend the upper surface of the brick at its ends. The bed of mortar is thus supported beyond the ends of the brick by the ledges of the clips, which prevent slumping of the mortar when the mold is removed, as this would result in a thinner bed of mortar at the ends of the brick before the next brick is put in place. The clips are removed after completion of the panel. The mold and clips are shown in Fig. 1.

The mortar is left in the bowl for 1 min following mixing, and then is quickly dashed from a small scoop into the mold so that in a few seconds the mortar is heaped above the top of the mold. A straight metal edge is moved across the top surface of the mold, scraping off the mortar $\frac{1}{2}$ in. above the brick surface. The mold is then lifted from the brick leaving the bed of mortar. The length of time the mortar bed remains on the brick before the next brick is placed on it has an important influence on the resistance of the panel to moisture penetration, and therefore is a factor that must be carefully controlled.

The second brick is placed on the mortar bed directly over the brick below, and immediately a tapping device is placed on it. This device consists of a flat plate with a cylindrical tube attached. A metal hammer is dropped in the tube to deliver an impact force to the brick, bedding it in the mortar. Two hammers, weighing 2 and 4 lb, respectively, have been used, dropping through a distance of $1\frac{1}{2}$ in. The impact force delivered to the brick is another factor that has an important influence on the "tightness" of the panel, and this too must be carefully controlled.

When the first mortar joint has been completed and the brick set in it, the mold is cleaned and placed on the upper brick. The same procedure is followed in laying another brick, with a freshly mixed batch of mortar.

The following schedule has been used in preparing panels when a time factor of 45 sec was desired between placing the mortar in contact with the brick and then placing the next brick on the mortar. The water, cementing materials, and sand are proportioned beforehand for the four batches required.

Time, min	Procedure
0	Start mixer, slow speed, and add sand to the bowl in first 20 sec (water and cementing material placed in bowl before mixer started).
2	Stop mixer, scrape down mortar into bowl, switch to medium speed, and start.
3	Stop mixer, allow mortar to stand in bowl.
4	Place mortar in form, scrape off excess, remove form from brick.
$4\frac{3}{4}$	Place brick on mortar and tap with hammer. Clean and dry the mixer bowl and blade, the mortar mold and other equipment. Prepare for second mix.
9	Start second mix. Mix as above.
12	Stop mixer, allow mortar to stand.
13	Place mortar in form as above.
$13\frac{3}{4}$	Place brick on mortar and tap. Prepare for third mix as above.
18	Start third mix.
21	Stop mixer, allow mortar to stand.
22	Place mortar in form as above.
$22\frac{3}{4}$	Place brick on mortar and tap. Prepare for fourth mix.
27	Start fourth mix.
30	Stop mixer, allow mortar to stand.
31	Place mortar in form as previously.
$31\frac{3}{4}$	Place brick on mortar and tap.

When the last brick has been placed, the panel has a vertical load of three bricks applied to it; this load is maintained until the test is made. During construction of the panel, the mortar bed resting on the metal ledges is removed, and the ledges taken off. The mortar surfaces at the sides of the panel must be level with the bricks to ensure that the panel will be well sealed in the test apparatus. To accomplish this, wet mortar is applied with a soft brush to the joints at the sides to bring them flush. The mortar joints of the front and back faces of the wall, however, are left as formed in the mold and are not tooled or otherwise treated.

The equipment used in making the panels is shown in Fig. 2. The mechanical mixer on the left is used to prepare the mortar; the mold for forming the mortar joint is shown in the center fitted over a brick. The scoop is used to dash the mortar into the mold; the mortar is scraped off with the metal straightedge shown on top of the mold. The tapping device is shown on the right, placed over a brick. It consists of a wooden base to which is attached a metal plate and tube, and a cylindrical hammer which is dropped $1\frac{1}{2}$ in. in the tube. The two dropping hammers are also shown. A completed panel with plastic sealing around the edges is shown behind the mold; beside it is a panel cut from brickwork removed from the wall of a building, similarly prepared for test.

Panel Curing

The panels are constructed, stored, and tested in a laboratory of controlled temperature and humidity (73 F, 50 per cent relative humidity). After a panel is made, it is covered on all surfaces with plastic sheeting for 24 hr. This covering is then removed from the face and back of the panel, but not from the side and top surfaces. The face and back are exposed to laboratory air until the panel is tested. For panels made of lime mortar, however, only the top and side surfaces are covered; the face and back of the panel are left exposed to the air immediately after it is constructed.

Before the test is made, the edges of the panel are sealed with a plastic adhesive, which is carefully spread over the surfaces with a putty knife. A

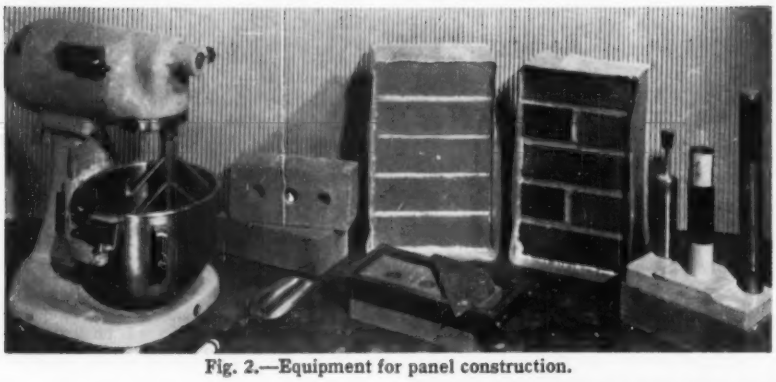

Fig. 2.—Equipment for panel construction.

sheet of 10-mil polyethylene plastic is placed over the adhesive, extending about an inch from the panel faces. At the bottom of the panel it acts as a deflector for any moisture moving down the surfaces.

The moisture penetration test is usually made 14 days after construction of the panel, and the test lasts for 24 hr. The panel is dried in the laboratory for two weeks or longer before the bond strength test is made, or companion panels for bond strength and leakage may be prepared for testing at the same age.

Moisture Penetration Tests

The panel is placed in an apparatus that sprays water on one surface of the panel to form a continuous film and at the same time applies air pressure against the wetted surface. A condition of test simulating heavy wind-driven rain is thus produced.

The panel is mounted in a frame constructed of steel channel members, 4 by $1\frac{1}{2}$ in. (Fig. 3). The panel is separated from the frame at the sides and top by a sheet of foamed plastic, $\frac{3}{4}$ in. thick, and at the bottom by a thin sheet of sponge rubber, about $\frac{1}{8}$ in. thick. One of the side members can be moved laterally by two screws, to bring the sponge plastic snugly against the sides of the panel. This side member is then secured to the base of the frame by a bolt. The top of the frame is connected by bolts to the side members and can thus be tightened against the sponge plastic laid on top of the panel. The panel is therefore firmly held in the frame and sealed at the edges by the sponge plastic, which also takes up any slight unevenness in the edges of the panel.

The test panel and frame form one wall of an air-pressure chamber also constructed of steel channel members (4 by $1\frac{1}{2}$ in.). The edges of the chamber are fitted with sponge plastic which provides an effective seal when the frame is bolted to the chamber. When the air-pressure chamber and panel frame are moved into position facing one another, bolts of the frame fit into slots in the chamber. Tightening the four nuts seals the two parts together. The other wall of the pressure chamber is made of clear plastic material which allows observation of the wetted surface of the panel during the test. Figure 4 is a sectional drawing of the frame and pressure chamber.

The water spray tube is a length of brass pipe with holes drilled along its length, spaced $\frac{3}{8}$ in. apart. The size of the holes is that obtained from a No. 76 drill. The spray tube is held in place near the face of the panel by a piece of metal attached to the tube which fits between the plastic and the top brick of

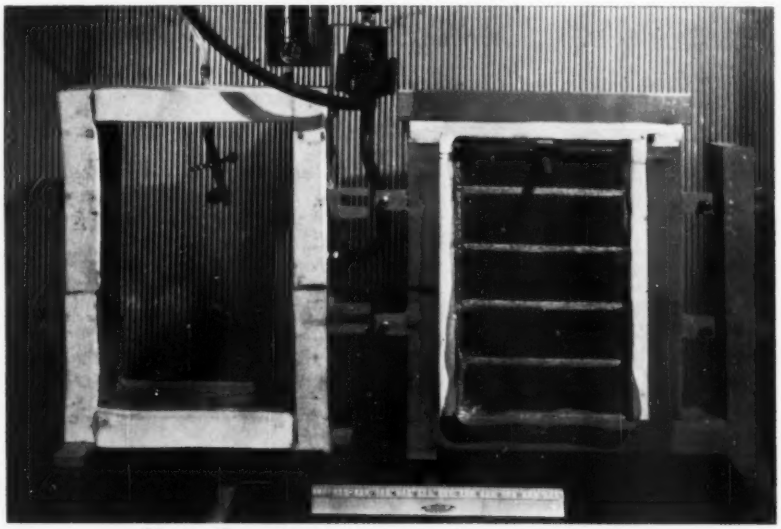

Fig. 3.—Frame for test panel, and air-pressure chamber.

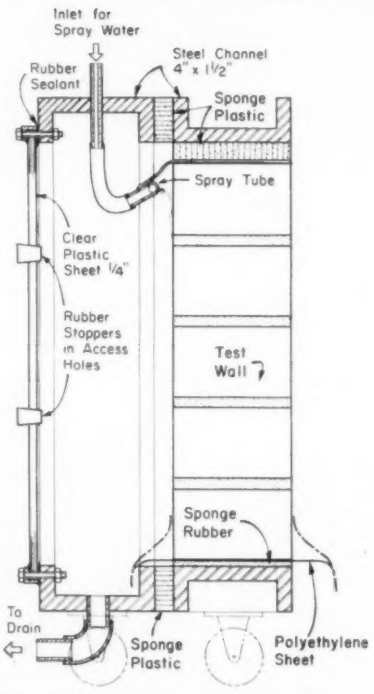

Fig. 4.—Section of air-pressure chamber and frame.

the panel. A constant-level water supply is connected to the spray tube, and a flow of water of about 600 ml per min is maintained through the tube.

The spray water enters the top of the pressure chamber and passes through a rubber tube to the spray tube. The water passes down the face of the wall and on reaching the plastic sheet is deflected away from the face and falls into the bottom of the pressure chamber. A tube leading from the base of the chamber carries the water to the drain. An air block is fitted in the drain tube to maintain the pressure in the chamber.

The wall of the pressure chamber is made of clear plastic sheet about $\frac{1}{4}$ in. thick and has two access holes. Immediately after the water spray is started a small brush is inserted through the access holes to spread the streams of water over the entire surface of the panel. Normally it takes considerable time for the small streams of water to establish a continuous film over the surface. When this had been done, the holes are sealed with rubber stoppers, as shown in Fig. 4, and the air pressure is applied.

The constant-level water supply to

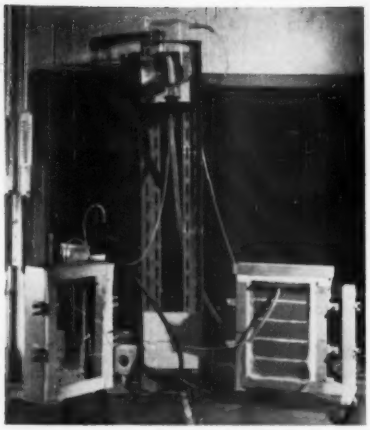

Fig. 5.—Apparatus for moisture penetration tests.

the spray tube is shown in Fig. 5. Water is brought from the tap to the inverted bottle. Two tubes lead from the stopper of the bottle. The large one is a drain tube to the sink and the other is the water supply tube to the pressure chamber. Water is supplied to the bottle at a rate exceeding the flow in the spray tube, and the excess is drained through the large tube. A constant level is therefore maintained above the spray tube.

As shown in Fig. 5, the water enters the top of the pressure chamber, passes by rubber tube to the spray tube (as indicated by the white cord), and then down the face of the panel. It is deflected by the plastic sheet at the base of the panel into the drain at the bottom of the pressure chamber.

The flow of air to the pressure chamber (from the laboratory supply) is regulated by a manual loading pressure regulator attached to the side of the chamber. The air enters the side wall of the chamber beneath the regulator valve, and a manometer mounted on top of the pressure chamber (shown in Fig. 3) indicates the pressure in the chamber.

During a test, the air pressure difference across the panel is maintained at 2 in. of water, which is approximately equivalent to the pressure of a 50-mph wind blowing against a wall. A record is made of the time taken for dampness to appear on the back of the panel, and of the rate at which leakage water comes off the back surface of the panel. The test is usually continued for 24 hr.

Bond Strength Test

The apparatus consists essentially of two clamps which hold the bricks on either side of a mortar joint and are pulled apart in a testing machine to determine the strength of adhesion between brick and mortar. The clamp is a metal frame or collar which fits over the brick. Four bolts in each side member of the frame bear against the curved surface of half-disks within the frame which act as swivels to conform to irregularities in the shape of the brick. When the bolts are tightened, eight individual flat bearing areas are moved against the sides of the brick. Strips of $\frac{1}{8}$-in. birch plywood or of leather are placed between the brick and the disks to produce a secure grip.

The procedure for clamping bricks is illustrated in Fig. 6. A clamping frame is placed over the bottom brick of the panel, supported at the mid-height of the brick by the wooden blocking shown. The frame is centered and the bolts are tightened uniformly. The panel with the clamp attached is then

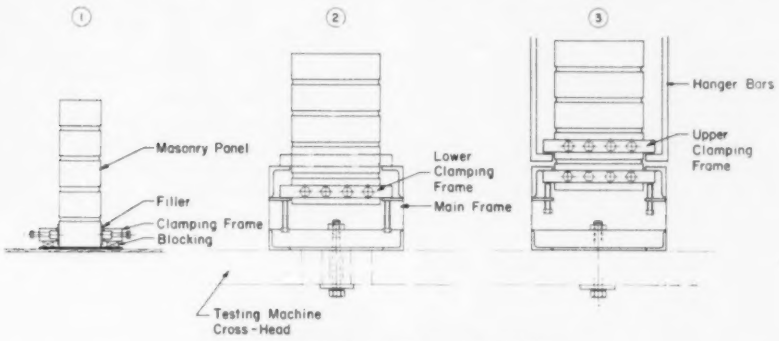

Fig. 6.—Procedure for clamping bricks.

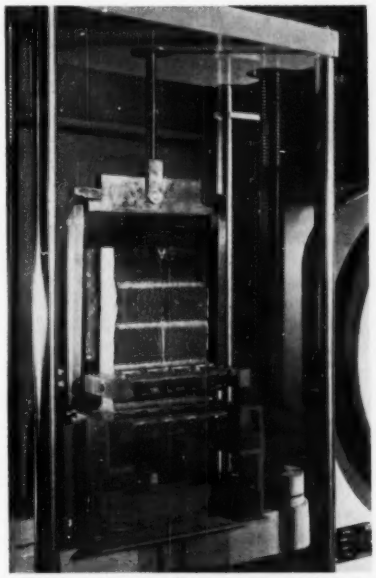

Fig. 7.—Apparatus for bond-strength tests.

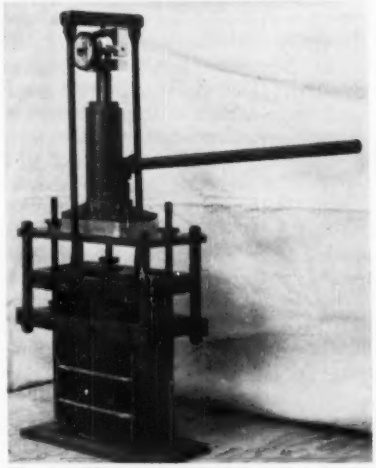

Fig. 8.—Manually operated apparatus for bond strength.

slid into a frame attached to the lower crosshead of the testing machine; the clamp rests on a flange, as shown in the second sketch. The clamp for the next brick is placed over the panel and rests on the upper part of the main frame where by design it is located at the mid-height of the brick. The bolts of the clamp are tightened to produce a secure grip to the brick.

Four vertical bolts in the flange are turned to raise the bottom clamp until it bears tightly against the main frame. In this way the bottom brick of the panel is attached to the crosshead of the testing machine, and it remains to attach the upper clamp to the loading head of the machine in order to pull the two bricks apart. Two hanger bars, shown in the third sketch, are attached to the ends of the upper clamp by means of ball-and-socket connections, and are attached above to a pivoted cross-bar or yoke suspended from the travel-arm of the testing machine. The apparatus is shown in Fig. 7.

In determining bond strength, the machine is set for a travel rate of 0.05 in. per min, corresponding to a loading rate of 1200 lb per min, and the breaking load is recorded on the dial of the machine. When the bottom joint of the panel has been broken, the clamp is removed from the detached brick and is fitted on the second brick of the remaining four by the same procedure described before, and the test is made on the next joint.

A similar apparatus was designed for use at the DBR Atlantic Regional Station in Halifax, which is not equipped with a universal testing machine. The apparatus therefore contained a small hydraulic jack to force the clamps apart and a load gage to record the breaking

force. The dial indicator of the load gage is equipped with a dead needle and is arranged so that it is not damaged when the load is suddenly released by breakage of the mortar joint. The apparatus is shown in Fig. 8. The jack is positioned above, and attached to, the lower clamp, while the upper clamp is joined to the travel-head of the jack by two hanger bars and a swiveling cross-bar. By pumping the jack handle the upper clamp is pulled away from the lower with the force indicated on the gage.

The clamping frames first described, for use with any suitable tension testing machine, were designed for tensile bond strengths up to 100 psi, leading to total loads of 3000 lb. It was found that bond strengths developed under laboratory conditions at ages up to 28 days were commonly below 30 psi, and so a simpler clamping arrangement was devised. These clamps have only two bolts per side, which bear directly on the brick, and are much more convenient to use.

With this hydraulic jack apparatus the top joint of a panel is the first to be broken. Each time a joint is broken both clamps are reset on lower bricks. The lower clamp is the first to be attached to a brick. A screw beneath the jack is then turned and lowered to bear tightly against the top brick. This places the mortar joint in compression so that it can better withstand any stresses resulting from the attachment of the upper clamp. When the upper brick has been clamped, the screw is raised from the brick. Before a test is made the nuts on two long threaded bars connecting the lower clamp to the base plate are tightened. In this way those joints beneath the one to be tested are maintained in compression during the test, thus increasing their resistance to damage from jarring when the joint being tested fails.

Summary

Strength of bond and resistance to moisture penetration are important properties of brick masonry. Since they depend on a multitude of factors, many samples are needed to study a particular factor, and the use of large wall sections is therefore expensive. For this reason a small-panel method has been developed, and an extensive program has been carried out and is continuing in the Division of Building Research to determine the influence of brick and mortar properties on moisture penetration and bond strength. In addition, studies are being made of the influence of some factors connected with the bricklaying operation, such as the time factor between placing the motor bed and then setting the brick in it, the tapping force applied in bedding the brick in the mortar, and the consistency of the mortar. These factors have been found to be of considerable importance; for many combinations of brick and mortar slight changes in them result in considerable changes in the moisture penetration and strength properties of the brickwork. Careful control of many factors in preparing panels for such tests is therefore necessary to obtain consistent results.

Acknowledgments:

The apparatus for bond strength tests was designed by N. B. Hutcheon and P. T. Hodgins of the Division of Building Research. This is a contribution from the Division of Building Research, National Research Council, Canada, and is published with the approval of the director of the division.

DISCUSSION

MR. C. C. CONNER.[1]—The panel method proposed by Mr. Ritchie for investigating moisture penetration of masonry and bond strength is open to serious question. There are strong indications that much of the information that would be furnished by this panel method in its present form would be inadequate or misleading. I feel, however, that satisfactory revisions could be made.

Panels never entirely reproduce the actual conditions of construction, but there is no good reason why they cannot closely approximate those conditions in the details of their construction. Panels are the only masonry available for laboratory experiments and have furnished much valuable information. The purpose of most panel testing is to predict what will happen or explain what has happened in actual building structures. Of prime importance is information regarding which combinations of brick and mortar will result in wall leaks and which produce moistureproof walls. The proposed panel test should be examined to see that this information is free from the mistakes of the past.

Panel and wallette tests in the past have been a poor guide to field practice. In the five more extensive laboratory investigations on moisture penetration of masonry (**1-5**),[2] three tests of high-cement mortars and low-suction brick—under an initial rate of absorption (IRA) of 5 g per min (**1, 3**). Excellent results were always obtained. This combination has been a complete failure in the field from a moisture-resistance standpoint. Four of the investigations (**1,3,4,5**) tested high-cement mortars and brick with suctions in the lower part of the moderate range—5 to 10 g IRA—and these combinations gave good or excellent results in three of the investigations (**3-5**). In my study of results in buildings (**6**) there were several buildings with high-cement mortar and brick with low-moderate suctions—9 to 14 g IRA. They all leaked—most of them badly—and the mortar joint cracking was far above the safe limit.

The results of panel testing with high-lime mortars have been quite inconsistent, and there were disagreements between investigations. The frequently good results with these mortars and high- and low-suction bricks were much better than has usually been obtained in the field (**6**). This prevented the test results with moderate-suction bricks—5 to 25 g per min—from being as outstanding as they should have been. The combination of high-lime mortar—1:1:5 or 1:2:7½—and moderate-suction brick has proved to be the backbone of moistureproof building construction. In my former company's building program it produced 176 moistureproof buildings during a 20-yr period.

The trouble with past panel testing seems to have been that small deviations from field construction practice have caused a great difference in results. This is particularly true when the difference in panel construction improves the initial bond. Measurements at buildings (**6**) showed that if the initial bonds between brick and mortar were good, wall leaks and mortar joint cracking did not develop unless there was excessive moisture movement; but if the initial bonds were poor, cracks

[1] Consulting Engineer, Verona, N. J. Formerly with Bell Telephone Company of New Jersey.

[2] The boldface numbers in parentheses refer to the list of references appended to this discussion.

between brick and mortar occurred, which continued to grow for several years. This growth of cracking has resulted in leakage in many buildings starting 1 to 5 yr after construction. Apparently, good initial bonds were usually produced in the test panels because in three of the laboratory investigations age and exposure did not increase the water penetration (**3**,**4**,**7**). Good initial bonds with high-cement mortars are not consistently obtained in the field, and this difference between results obtained in buildings and in panels can be explained only by a difference in construction practices.

To obtain good initial bonds there must be good initial contact between brick and mortar. In the field, this contact is provided by workability in the mortar. Low workability in the mortar reduces the completeness and intimacy of contact, and so does a low rate of absorption in the brick. This latter, apparently, permits a film of water to collect between brick and mortar which interferes with the intimacy of the contact and the bond. High suction in brick apparently destroys the initial contact in many areas before the bond can form, and there may be other interferences with initial contact. If the brick is forced into contact with the mortar and the contact is not disturbed, good bonds will form. The better results in panel tests (**1**–**5**) indicate that the initial contacts and bonds between brick and mortar were better in panels than in the field.

The hammer blow applied to each brick in the panel, as suggested in Mr. Ritchie's proposed panel test, would, in most cases, force good initial contact between brick and mortar regardless of their properties. This would reduce the formation and growth of separation cracks between brick and mortar, which is the major cause of moisture penetration of masonry. The advantages of good mortar workability would vanish (apparently), and any water film between mortar and impervious bricks would be driven out. This good contact could be partially destroyed later by a high rate of absorption in the bricks, but even so, the harmful effects on bond would probably be reduced by the hammer blows. The hammer-blow technique would invalidate any attempt to reproduce actual construction conditions.

One of the major problems of panel testing is the lack of consistency in results, and their poor reproducibility. The hammer blows would undoubtedly improve the consistency and reproducibility of the test results, but the results would not properly reflect what actually happens under field conditions. It would seem that any procedure, not common to normal field practice, which reduces the usual variability of test results would, of necessity, have to inhibit the action of some forces that normally influence results in actual construction.

Other laboratory investigators have used other devices to achieve reproducibility. Palmer and Parsons (**8**) and Palmer and Hall (**9**) produced much the same effect as the hammer blow by having the bricklayer throw his full weight on each brick and maintain that pressure for 1 min as the bricks were laid in couplets and piers. This procedure enabled them to obtain the relatively complete contact and extent of bond they needed to make their comparative bond studies. Palmer and Parsons built their wallettes for moisture penetration tests (**1**) by spreading the mortar for one brick at a time and laying the brick immediately. They had found in a previous study (**8**) that low-water-retention mortars could not be spread out over four bricks without loss of bond. I understood they followed the practice of their previous work and laid these bricks with heavy pressure, but this is not mentioned in their paper. Their method of laying bricks produced wallettes where the most resistant to moisture penetration were those built with a combination of high-cement mortar and impervious bricks. Palmer and Parsons were fully aware that this combination had not produced good results in the field and pointed this out in connection with impervious bricks.

Other devices used to achieve reproducibility in bond tests have been the painting of each brick with grout from the mortar before laying; and the spreading of half of the joint thickness of mortar on each brick before laying in couplets.

Evidently the way the bricks are laid greatly affects the test results in panels. Such artificially produced results can be misleading. The excellent results obtained in the early laboratory investigations with high-cement mortar and impervious bricks were widely circulated, and it took years before the building industry could free itself from this detrimental combination of brick and mortar with its hair-cracked mortar joints and wall leaks. In my study of the moisture resistance of actual buildings (**6**), seven buildings had this combination of low-workability, high-cement mortar and low-suction brick. All seven leaked, and most of them severely.

The evidence in this field study (**6**) of results at 100 building units, where 46 leaked and 54 did not, contradicted much of the evidence from the laboratory investigations on panels and wallettes. The field study indicated that both poor workability in mortar and low suction in bricks were detrimental to the moisture resistance of masonry walls. In 27 buildings the high-cement, low-workability mortars—1:3 mixes with 10 to 25 per cent of lime added—were used. Twenty-six of these buildings leaked; the single exception had grout poured into the center of each brick course as laid. Thirteen of the 26 buildings had good, moderate-suction brick, but the lowest joint cracking recorded was 26.0 per cent—26 ft of cracks per 100 ft of mortar joints—which is about twice the safe limit. The consistent failure of high-cement mortar in actual buildings is directly counter to the record in panel tests of excellent resistance to moisture pentration with low-suction bricks, and usually good or excellent resistance with moderate-suction bricks (**1**–**5**). The failures in buildings could not be ascribed to poor workmanship. There always was competent and rigorous inspection, standards were high, and the contractors were carefully selected. As a result, workmanship was consistently much above the average.

Evidence on the effects of low-suction bricks in this same study (**6**) was less extensive, but the influence seemed definitely detrimental. All of the seven buildings with low-suction bricks and poor-workability mortars leaked, as did two of the four buildings with low-suction bricks and workable, high-lime mortars. The average cracking with the workable mortars was high—20.4 per cent. Many other field observations have apparently confirmed these findings. Here again, panel tests showed a different trend, the low-suction bricks having a consistently good record with all mortars (**1**–**4**).

The favorable laboratory record of the combination of high-cement mortar and low-suction brick seems incredible to old-time construction men. That combination of brick and mortar became so notorious for causing leaky, buildings and hair-cracked mortar joints that competent builders stopped using it many years ago. It cost my former company close to a quarter of a million dollars to remedy one such condition. Measurements at that building, taken five years after construction, showed 68 ft of joint cracks per 100 ft of mortar joints, although the workmanship was excellent. The entrance and resulting freezing of water caused many of the cored bricks to crack or split. Panel tests, however, would have indicated that the 3.0-g IRA brick and high-cement mortar was an excellent combination.

Demolition work supplies some pertinent evidence. Where there is much joint cracking and wall leaks, the demolition shows a wide variation in the extents of bond between brick and mortar—some good, some poor, and some with tentacular bonds. This

serves to explain the inconsistency of many panel tests. However, there have been very few partially bonded bricks observed in walls where a good combination of moderate-suction brick and a workable 1:1:5 or 6 high-lime mortar has produced a wall with a low percentage of joint cracking and no leaks. Contractors have learned to dread the demolition of such walls. There are no cleavage lines and no separation of individual bricks. The salvage of bricks gets down to chipping off the mortar bit by bit. The evidence from demolition suggests that inconsistency in bond may well be the normal condition of a poor combination of brick and mortar, as consistency may be evidence of a good combination. There is much we need to know about the causes of separation cracking between brick and mortar.

The recital of the misleading indications of past results in panel testing should not be taken to mean that panel tests are of little value in the study of masonry. Revisions can be made that will make them much more valuable in the future than they have been in the past. Obviously, panel tests must be able to produce results comparable to those obtained in buildings under the same general conditions. In the past they have failed to do so in many particulars. I submit for Mr. Ritchie's consideration some comments and recommended changes I believe would help bring his proposed test into line with actual construction conditions:

1. The pressure and thrust used in laying the bricks in the panel should match that used in the field. This will require a study of the pressure and thrust exerted by several skilled bricklayers and probably some mechanical means of laying the bricks with no more and no less than the determined pressure. Also, it may be necessary to use a "backstop" at one end of the panel to take the thrust without disturbing other bricks in the panel.

Determining the proper pressure will take some doing, because I suspect all masons use more pressure in laying bricks in panels—or in tests—than they do in their daily bricklaying. This may well be a major reason why panel results are usually better than those obtained in buildings.

2. I believe the 45-sec time lag between the spreading of the mortar and the laying of the brick as proposed by Mr. Ritchie is too short. The proper period of waiting time would have to be determined to approximate that normally occurring in the field in the building of high-grade brickwork. I suggest the time lapse be the time between the start of the spreading of the mortar over three bricks and the laying of the second brick in the top course.

3. For the sake of consistency in results, the initial rate of absorption of the brick, the plasticity of the lime, and the grading of the sand, must be kept constant during a test program. Sand is likely to be a variable, which affects results. The proposed requirement that sand pass the proper ASTM specification is not enough. The grading should be specific, and percentages should be maintained within ±2 per cent.

4. The mortar mixes in Mr. Ritchie's proposed panels would be proportioned with compacted dry sand. In field construction, damp sand is almost invariably used. Numerous tests on damp sand from piles in the field showed shrinkages of from 22 to 24 per cent when the sand was inundated, as is the case in mortar. Dry rodded sand also shrinks when inundated, but only about two per cent; and loose dry sand shrinks about 12 per cent. I suggest that the weight of sand in the mixes be the weight of the sand only in equal volumes of damp sand, a reduction of about 21 per cent from the dry rodded weight. There are other acceptable methods of arriving at the equivalent weights of damp sand, but for results comparable to those obtained in the field, the damp sand weights, less the water, should be used.

5. The mortar beds in the proposed panels are recessed $\frac{1}{8}$ in. at the test face, and are not tooled. The mortar, when pushed out by the pressure of laying the top brick, would tend to slump away from the brick above, and would make poor contact with the brick below. This would provide water entrances. If there are any brick ledges left exposed, they would guide the water in, as happens with raked joints. In the proposed panels, the absence of a recess at the brick ends serves as a stop to water penetration through perimeter separation, but poor contact at the face would be an undesirable hazard.

Joint tooling has an important effect on the moisture resistance of field masonry (6). Joints filled to the testing face and concave-tooled are recommended for the panels. This would be more comparable to field construction. Moreover, workable mortars that can be tooled easily and effectively into good contact and bond with the bricks at the joint face would improve the moist resistance. Their superiority would be reflected in the test results.

6. The hammer-blow technique should be abandoned. It is a deviation from field practice and would tend to inhibit some of the forces acting on field masonry. It would obscure the beneficial influence of good mortar workability and the harmful effects of low mortar workability and low brick suction on the moisture resistance of masonry. It might cover up the influence of other factors. Data derived from tests on panels constructed with the hammer-blow technique would not properly warn against the use of undesirable mortars and bricks and would certainly produce a distorted and misleading picture of the problem of water penetration of masonry and its solution.

MR. T. RITCHIE (*author's closure*).—The criticisms made by Mr. Connor are useful since they clearly draw attention to possible inadequacies of small-panel testing of brick masonry and to the possibility that misleading information may be obtained from such tests. Comments should be made on certain parts of the discussion, however, since a different interpretation may be placed on some of the points raised.

Panel and wallette testing in the past are said to have provided a poor guide to performance in the field. The particular case is mentioned of the combination of low-suction bricks and high-cement mortar which has invariably given good results in laboratory tests but "complete failure" in the field. Mr. Connor believes that this situation is the result of differences in construction practice, that laboratory-built brickwork has differed in the manner of construction from "field" brickwork, with the result that in the former case the initial bond between brick and mortar is better than that normally obtained in the field. Although it is agreed that low-suction bricks frequently have been involved in problems of leakage, I do not believe that lack of initial bond is the reason. On the contrary, I believe that low-suction bricks under conditions of both laboratory and field construction bond well initially with mortar, and the resistance to moisture penetration at an early age is high, as laboratory tests have indicated. Low-suction bricks, however, especially when used with a strong, high-cement mortar, are likely to produce very rigid masonry which is sensitive to conditions of stress. When subjected to the stresses normally imposed on it in service the integrity of this masonry and its resistance to moisture penetration may be lost. Mr. Connor's observations on the behavior of brick masonry in walls appear to confirm this, since he notes that in many cases leakage started 1 to 5 yr after construction and there was a growth of cracking in the brickwork with age.

The results of exposure tests of panels of low-suction bricks, in which no change in leakage characteristics took place from the weathering of the panels, may well have been misleading, as Mr. Connor suggests, but probably not because of differences in initial bonding so much as differences in restraint and stress. The brickwork of a test panel is unrestrained, whereas that of a wall

is not, since it is much larger in expanse, turns corners, and may be tied into other parts of the building, such as columns. The performance of similar brickwork under these two different conditions of service may be expected to be different, and the difference must remain a serious weakness in panel tests unless some method can be developed to build into test panels the same conditions of restraint that might occur in walls. In any case studies such as Mr. Connor's on the performance of masonry in actual buildings will finally reveal the adequacy of a particular combination of unit and mortar.

Important differences between laboratory and field masonry may arise, as Mr. Connor suggests, from differences in the proportioning of the materials used to prepare mortar. In laboratory work, proportioning of materials usually is very carefully controlled, and, in general, the proportion of cementing material to sand is low. In the field there is usually much less control of the proportioning, and it is often governed to a large extent by the working properties or "feel" of the mortar. It is suspected that when a cementing material of low "workability capacity" is to be used in the field its poor qualities in this respect are compensated for by making the mix richer. Greater rigidity and strength in the mortar would result from this, along with greater dimensional instability, and therefore, a promotion of cracking in the wall and breakdown of the bond.

Mr. Connor has noted that in laboratory work sand is usually proportioned in a relatively dry condition, whereas damp sand is used in the field. This also would affect the richness of the mix, since a 1:1:5 mortar prepared with damp sand in the field would be equivalent to a 1:1:3¾ mix prepared in the laboratory from dry sand, assuming a difference of 25 per cent in volume of the sand because of its bulking from moisture. For two reasons therefore, workability and sand bulking, it is probable that much richer mixes are used in the field than in the laboratory; observations made in DBR studies of masonry have indeed indicated that extremely rich mixes are often used in the field.

Attention has been drawn in Mr. Connor's discussion to the problem of devising a standard laboratory method of laying bricks to duplicate the pressure and thrust used by the bricklayer under field conditions. Unfortunately, for reasons discussed later, there does not appear to be a uniform, nonvarying bricklayer's technique. A mason's method of bricklaying is a variable that changes as other factors change, and undoubtedly there is a variation from one bricklayer to another. In the laboratory method of constructing brickwork, the use of a hammer to tap bricks into the mortar bed has been criticized as a departure from normal practice that produces bonding entirely different from that obtained in the field. This does not appear to be the case in this area (Ottawa, Ontario). On several occasions observations have been made of bricklaying methods, and it was noted that the technique used was not to shove the brick into the mortar but rather to set it on the mortar and then to tap it down to the line with the edge of the trowel. The tapping usually consisted of four or five sharp, rapid taps rather than the single tap used in the laboratory method. The brick was held in the hand while it was tapped into place, but there did not appear to be any pressure from the hand that might be termed "shoving." The bricks used locally are, as a rule, moderate to high in suction, and it is not known whether the same method applies to low-suction bricks. Differences between the laboratory method and field methods may occur, but apparently not in whether tapping is characteristic of one and not the other; the nature of the tapping, however, may be different.

Bricklaying methods appear to vary considerably with the type of brick and mortar; with moderate-suction bricks the bedding is done with light tapping, but with higher-suction bricks heavier tapping is necessary to bring the brick down to the line. It seems clear also that the consistency of the mortar is varied with the suction of the brick used if the bricklayer has any control over the tempering of the mortar. A particular mortar almost invariably is used in a much wetter state with high-suction bricks than with those of moderate suction. The length of time the mortar is in contact with the bricks beneath it before a brick is set on the mortar bed may be varied considerably by the bricklayer, and to some extent it varies with the type of brick and mortar used. If the bricklayer in building a wall spreads out a mortar bed for three bricks, the result may be three different bonding conditions between brick and mortar, since the properties of the mortar continuously change due to the absorption of the bricks below. The poorest-bonded brick will be the last of the three placed in the mortar. A situation could therefore arise in which one third of the bricks placed in a wall have inadequate bonding in regard to resistance to moisture penetration, while the remaining bricks are adequately bonded. Observations of bricklaying in the field indicated that the time interval may vary from as little as 20 sec for the first brick laid to as long as 1½ min for the third.

Mr. Connor's discussion has served well to illustrate some of the complications that arise in making panel tests of brick masonry, and there is no doubt that such tests may be inadequate. Panel tests are used because they provide the only practical means of obtaining fundamental information on brick-mortar bonding and the factors affecting it. It is necessary to resort to such tests to eliminate the variables inherent in field construction, and even with their inadequacies panel tests appear to be extremely useful in revealing the influence of certain factors on the performance of brick masonry.

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The Development of More Stable Gage Blocks

By M. R. MEYERSON, T. R. YOUNG, and W. R. NEY

American precision tool manufacturers have requested a higher degree of accuracy in gage blocks and their calibration than is currently available in order to keep pace with the needs of the missile, aircraft, and other precision industries. To meet this need, a long-range research program aimed at an accuracy of one part in 10 million in gage-block length calibrations is under way at the National Bureau of Standards. Significant advances have been made recently with the development of highly stable blocks and ultraprecise measurement techniques. This paper describes the highlights and presents the data obtained in the initial phases of the program.

THE need for greater precision in production for the atomic and space age has created a demand for gage-block length calibrations more accurate by an order of magnitude than the best available today. The satisfaction of this demand requires the development of: (1) measurement techniques capable of this accuracy, and (2) stable gage materials capable of retaining dimensions to this order of magnitude over a useful period of time. To date a program at the National Bureau of Standards[1] has made significant progress in meeting both of these requirements.[2] Rapid length comparison techniques which increase the precision of measurement from 1 to 0.1 or 0.2 microinch per in. have been evolved. Gage blocks developed from two different materials have shown dimensional change at a rate equal to 0.2 microinch per in. per yr as measured over the period of approximately one year.

Thirty Years of Progress

Over a period of 30 years, tolerances in precision of manufacturing have changed from 1 part in 10,000 to the present requirement. In actual practice gage blocks need to be about ten times as accurate as the objects being measured. For example, a current commercial gage block with a length tolerance of 2 ppm is used to measure no closer than 10 or 20 ppm. This tenfold spread serves to compensate in part for inaccuracies due to dimensional instability, wear, and the summation of errors occurring in combining two or more blocks. Eleven blocks, purchased more than 30 years ago from a common source and said to be of the same chemical composition and to have received identical heat and stabilizing treatments, have been observed for dimensional stability at the Bureau since their procurement. Some have grown constantly over this entire period (up to 20 microinches per in.), others have not varied more than 2 microinches per in., and the rest have remained stable or have shrunk slightly for a period of one to seven years and then have proceeded to grow. Two of the more stable and two of the less stable blocks were independently analyzed for retained austenite at The Timken Roller Bearing Co. and the National Bureau of Standards; the results at the two laboratories agreed closely. The two more stable blocks contained about 11 per cent of retained austenite, the least stable of the four had 20 per cent, and the other unstable block had 15 per cent. These tests indicate not only the large variation in stability that may be obtained with what is presumed to be very small variations of composition or treatment, but also the inadequacy of judging dimensional

NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] M. R. Meyerson, T. R. Young, and W. R. Ney, "Gage Blocks of Superior Stability: Initial Developments in Materials and Measurements," *Journal of Research*, Nat. Bureau of Standards, Section C, July–Sept., 1960.

[2] Industrial firms actively participating in the program are: Brown & Sharpe Mfg. Co.; Dearborn Gage Co.; DoAll Co.; E. I. du Pont de Nemours & Co., Inc.; Fonda Gage Co.; General Electric Co.; Greenfield Tap and Die Corp.; Hughes Aircraft Co.; International Business Machines Corp.; Link Aviation, Inc.; New Departure Division of General Motors Corp.; Pratt & Whitney Co., Inc.; Taft-Peirce Mfg. Co.; The Sheffield Corp.; The Timken Roller Bearing Co.; The Van Keuren Co.

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stability on the basis of short-time observations. These blocks also supply evidence that the presence of some retained austenite need not necessarily promote dimensional instability, and may in fact contribute to stability. Moreover, observations based on measurements of one year or less and indicating a desirable degree of stability, while a favorable sign, cannot be interpreted as final. Conversely, an indication of instability during the first year may portend instability during future years, although the degree may change and exceptions have been noted.

Commercial blocks available today, made to conform to Federal Specification GGG-G-15, June 7, 1956, for Laboratory Grade AA, have a tolerance of 2 microinches per in. at the time of purchase. There are no definite quantitative requirements for subsequent dimensional stability, only the statement ". . .suitably treated to assure dimensional stability of the finished gages."

The problem of achieving gage blocks dimensionally stable to the desired degree has two aspects:

1. A suitable material must be selected or developed and subsequently treated to produce a gage block with a high degree of dimensional stability, surface finish, surface flatness, and parallelism of opposite gaging faces. Thermal expansion and thermal conductivity should be similar to that of the material being measured. Resistance to wear, to deformation, and to atmospheric and fingerprint corrosion should be high.

2. Instrumentation and techniques for the measurement of temporal changes of length need to be developed, so that stability of experimental gage blocks may be determined to the required precision. Calibration of the large number of experimental gage blocks anticipated indicates a need for the development of rapid measuring techniques. .

Three Approaches to the Materials Aspect

The first approach to the materials aspect was to select steels similar to those in general use for gage blocks and improve their stability to the desired limits. Dimensional instability is believed caused by structural changes and the redistribution of residual stresses within the gage block, and possibly to some extent by the relief at room temperature of residual fabrication stresses. It was concluded that improved stability in through-hardened blocks could be achieved only by balancing contractions caused by room-temperature decomposition of martensite and expansions caused by transformation of austenite, with changes in volume due to changes in the residual stress system —a formidable task. The technique adopted was: (1) to devise a process to remove almost all of the austenite so that additional transformation could not occur, (2) to temper for long intervals or at a slightly higher temperature to accelerate the decomposition of martensite, (3) to take particular care with grinding operations or eliminate them entirely on nongaging faces, and (4) to stress relieve after the final grinding operation.

The second approach was completely different and seemed at first to hold more promise. If a fully annealed single-phase material could be used there would be few, if any, driving forces left within it to cause dimensional changes; however, fully annealed materials are too soft for gage blocks, they cannot be lapped well, and the surfaces would wear excessively. Furthermore, the coefficient of thermal expansion of pure metals or single-phase alloys is usually high.

A compromise seemed to offer a reasonable solution, and accordingly several alloys with low-alloy content and alloys which had only small amounts of a second phase in the annealed condition were selected. A hard surface was produced on gage blocks of these materials by one of several methods: nitriding (gas and liquid), coating with tungsten carbide or aluminum oxide, coating with a hard alloy material, chromizing, electroplating, carburized case hardening, and carbonitriding. The nitriding procedure was particularly tempting because it permitted stress relieving temperatures near 1000 F without a resulting drop in hardness. As with the first approach where fully hardened materials were used, considerable attention was paid to grinding stresses, and many of the gage blocks were not ground on the nongaging surfaces after processing.

The third approach was to select specific nonmetallic or partially metallic materials which by their nature are considered inherently stable, hard, and corrosion resistant. It was found that most of these materials lacked at least one desirable property, such as proper thermal conductivity. It was concluded, however, that if a metallic gage block with all the desirable features was not found, it might be necessary to accept a material of this kind.

TABLE I.—MATERIALS CONSIDERED FOR USE AS GAGE BLOCKS.

Hardenable Throughout by Heat Treatment	Surface Hardened with Core in Annealed Condition	Hard and Stable, Purchased and Fabricated to Bureau Specifications
52100[a] modified steel	1010 steel	Titanium carbide A
D2 tool steel	W4 tool steel	Titanium carbide B
T15[b] modified tool steel	8620 steel	Titanium carbide, steel binder
	304 stainless steel	Aluminum oxide
	405 stainless steel	
	410 stainless steel	
	420 stainless steel	
	17-4 PH stainless steel	
	Nitralloy 135 modified	

[a] 52100 modified by addition of 0.27 per cent molybdenum.
[b] T15 modified by additional vanadium and tungsten.

Methods of Treatment and Results

At present 16 materials (Table I) are under investigation and have been given a total of 42 different treatments. The steels in the left column of Table I are hardenable throughout by heat treatment (the first approach discussed above). Those in the second column have been surface-hardened with the core in an annealed condition (the second approach). Those in the third column, which were innately hard and possibly stable, have been purchased and fabricated to the Bureau's specifications (the third approach). There has been some overlapping in the use of materials; for example, the 52100 modified[3] has been given a hard coating with an annealed core, as well as being used in the hardened condition.

The 42 different treatments have been used to produce about 800 experimental blocks. Each block has a gage length of 2 in. and has nongaging dimensions of $1\frac{3}{8}$ by $\frac{3}{8}$ in. Those of each type with the best-finished gaging faces have been selected for stability measurements. As it takes some 18 months from the time a desirable treatment is established until the blocks are processed and sufficient stability data are available to establish a trend, data on only two of these steels, 52100 and 410 stainless, given a total of 14 treatments, are presented here. These were the first to undergo treatment, and gage blocks made from only these two have been available for enough time to permit sufficient observation. It should be emphasized again that stability characteristics observed during the first year of observation are not necessarily carried over to succeeding years. Changes in length are reported in microinches per inch, which is a matter of convention and convenience and should not be construed as being directly convertible to any size of gage block, particularly those of less than 1 in.

The most stable blocks observed to date were made from the annealed 410 stainless steel nitrided in two stages to

[3] Henceforth, text references to 52100 steel pertain to this modified type.

a depth of 0.009 in., ground on only the measuring faces to within 0.003 in. of finished length, stress relieved for 3 hr at 975 F in a cracked ammonia atmosphere, and then finished by lapping the gaging faces, leaving a case of about 0.005 in. The nitrided surfaces of the nongaging faces were not ground after nitriding. Similar stability characteristics were indicated in another set of nitrided blocks of annealed 410 stainless steel in which the frosty (white) layer only was removed from the nongaging faces by careful grinding.

The results for the most stable sets of nitrided 410 stainless steel blocks are given in the first and second items of Table II, and for the individual blocks are given in Fig. 1 (*a* and *b*). As noted in this table, these blocks showed an average change in length of 0.2 microinch per in. per yr.

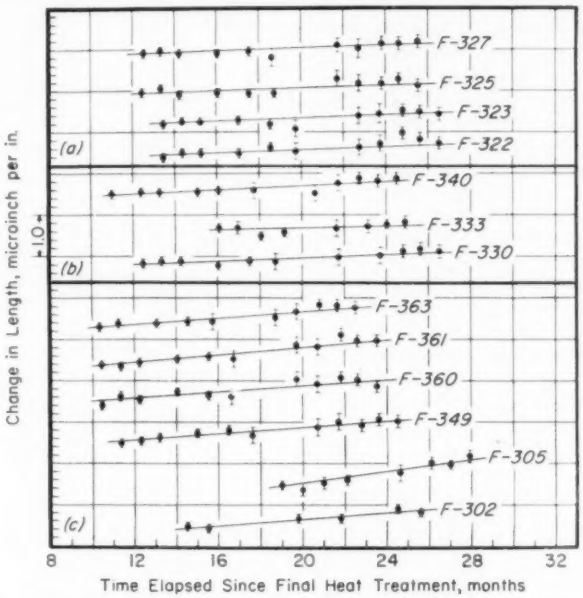
The over-all stability of the best through-hardened 52100 steel gage blocks for the period of observation was 0.4 microinch per in. per yr. However, they exhibited excellent stability, with dimensional change at the rate of only 0.1 microinch per in. per yr after an initial six-month period of much less stability. These 52100 steel blocks were heat treated by austenitizing at 1550 F for 15 min and quenching in an oil compounded for fast quenching. They were stabilized by immediately (within 5 sec) refrigerating at −140 F

TABLE II. STABILITY OF GAGE BLOCKS OVER A ONE-YEAR PERIOD, IN ORDER OF MERIT.

Steel and Treatment[a,b]	Average Change in Length, microinch per in. per yr
1...410 stainless steel, two-stage nitrided, nongaging faces left as nitrided	+0.2
2...410 stainless steel, single-stage nitrided, white layer removed from nongaging faces	+0.2
3...52100 steel, hardened and tempered to 65 R_c	−0.4
(after 6th month)	(−0.1)
4...52100 steel, gaging faces coated with thermally sprayed Ni-Cr-B alloy	+0.4
5...52100 steel, hardened and tempered to 60 R_c	+0.4
6...52100 steel, all faces electroplated with chromium	−0.4
7...52100 steel, hardened and tempered to 62 R_c	+0.5
8...410 stainless steel, single-stage nitrided, cases completely removed from nongaging faces	+0.6
9...52100 steel, gaging faces coated with flame-plated tungsten carbide	+0.7
10...52100 steel, hardened and tempered to 60 R_c, ground perpendicular to 2-in. dimension	−0.7
11...52100 steel, hardened and tempered to 62 R_c, ground perpendicular to 2-in. dimension	−0.9
12...410 stainless steel, gaging faces electroplated with chromium	+1.0
13...Commercially manufactured, Laboratory Grade AA	−1.1
14...410 stainless steel, gaging faces coated with thermally sprayedN i-Cr-B alloy	+1.3

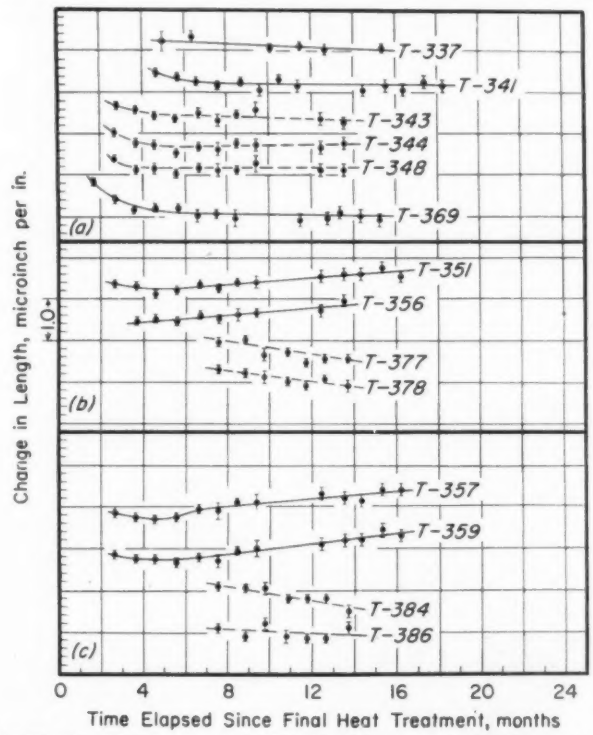
[a] Nongaging faces on all blocks ground parallel to the 2-in. (gaging) dimension except where indicated.

[b] All blocks that were hard coated were in the annealed condition.



(*a*)—Nitrided by two-stage process, nongaging faces left as nitrided.
(*b*)—Nitrided by single-stage process, white layer removed from nongaging faces.
(*c*)—Nitrided by single-stage process, nitrided case completely removed from nongaging faces.
* Each plotted point has an upper and lower limit which is the estimated precision of the determination. This estimate was based upon the statistical information derived from the test itself.[1]

Fig. 1.—The stability of nitrided, initially annealed 410 stainless steel gage blocks.



(*a*)—Hardness 65 R_c (*b*)—Hardness 62 R_c (*c*)—Hardness 60 R_c

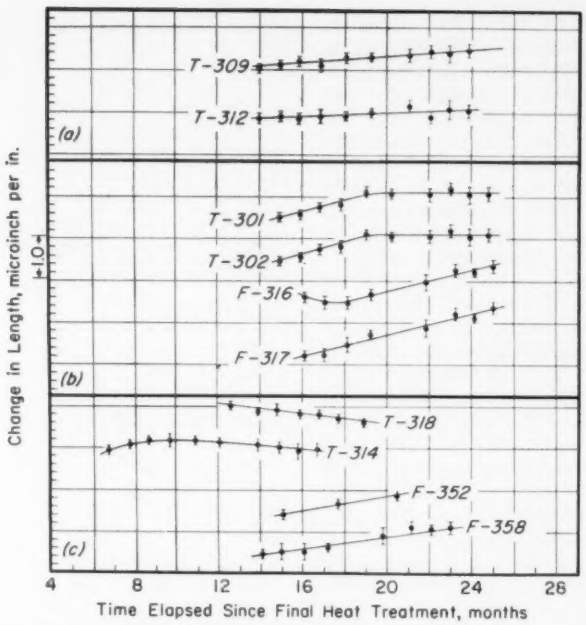
Fig. 2.—The stability of hardened and stabilized 52100 steel gage blocks. Solid lines represent martempered blocks, dashed lines represent directly quenched blocks.

for 18 to 22 hr, tempering at 250 F for 1 hr, immediately refrigerating a second time at −140 F for 18 to 22 hr, and tempering a +250 F for 9 hr. The blocks were ground and then stress-relieved at 240 F for 3 hr before final lapping. This treatment reduces the retained austenite content to less than 2 per cent and produces blocks of satisfactory hardness (65 Rockwell C scale). The results are noted in the third item of Table II and in Fig. 2 (*a*).

A fourth type of block that shows promise, and which has been under observation for stability for almost a year, is of annealed 52100 steel coated on the gaging face to a depth of 0.004 in. with tungsten carbide. After surface grinding and lapping, a coating of about 0.0025 in. remained, providing a hard facing. These blocks were given a stress-relieving treatment in cracked ammonia at 975 F for 3 hr before lapping. An extrapolation of available data indicates that the overall growth of such a block is 0.7 microinch per in. per yr, but a substantial improvement in stability during recent months suggests that a much higher stability may be achieved. (See data for blocks T-301 and T-302 in Fig. 3 (*b*).)

Several commercial hardened-steel gage blocks of the highest quality (AA grade) were purchased from different manufacturers and observed for stability in the same manner as the blocks developed at the Bureau. This was done to provide a standard of comparison, and to provide familiar types of blocks and materials for testing and correlating the instrumentation and techniques of measurement under development. All of these blocks became shorter with aging by amounts ranging from 0.7 to 1.9 microinch per in. per yr, extrapolated over a period of one year, with an average shrinkage of 1.1 microinch per in. for a year. The stabilities of these commercial blocks are shown in Fig. 4.

Other treatments given the two steels, 52100 and 410, and the results of stability tests on them are summarized in Table II and Figs. 1, 2, and 3. None of these was as stable as the first three types in Table II, which were described previously. Items 5 and 10 in Table II were heat-treated identically, as were items 7 and 11. The only other difference in the pairs of identically heat-treated blocks was in the direction of grinding of the non-gaging faces. Item 5 was ground parallel to the 2-in. gaging dimension, and item 10 was ground perpendicular. Likewise, item 7 was ground parallel and item 11 perpendicular. Yet, the blocks that were ground parallel grew, and those ground perpendicular shrank. An X-ray analysis of the residual stress pattern, made at The Timken Roller Bearing Co. on similar gage blocks, revealed compressive residual stresses on the order of 14,000 psi in the direction parallel to grinding and 60,000 psi in the direction perpendicular to grinding. It is believed that the orientation of these stresses was significant in producing a growth in two sets and shrinkage in the other two. Additional study designed to clarify this phenomenon is underway.



(*a*)—Gaging faces coated with thermally sprayed nickel-chromium-boron alloy.
(*b*)—Gaging faces coated with flame-plated tungsten carbide.
(*c*)—Faces electroplated with chromium, T-blocks on all faces, F-blocks on gaging faces only.

Fig. 3.—The stability of initially annealed 52100 steel (T-blocks) and 410 stainless steel gage blocks (F-blocks) with hard coatings.

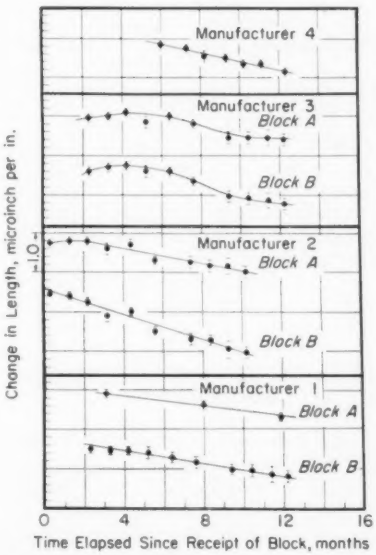


Fig. 4.—The stability of commercial gage blocks of "AA" grade obtained from four manufacturers.

Development of Ultraprecise Measurement Techniques

To establish the change in length of the test specimens it was necessary to refer to a length scale whose stability characteristics were known. An ideal procedure would be by absolute measurement when the specimen is compared with a length scale formed by the interference of light of known wavelength. It is generally believed that a wavelength of light is constant with time.

An idea of the degree of precision of the absolute length measuring methods that have been used for the past several years in calibrations can be obtained from the measurement history of a 2-in. steel block selected as the control block for the stability measurement program at the Bureau. In 33 absolute measurements made on this comparatively stable block between Jan., 1954, and Dec., 1957, the largest deviation of a single measurement from the average of all measurements was 1.2 microinch. The standard deviation for a single measurement was 0.55 microinch. Today, with the increasing demand for gage blocks reliable to 0.1 or 0.2 microinch, the need for more adequate measuring equipment is apparent. Therefore, the development of a precise absolute interferometer has been given high priority in the project at the Bureau, since there are no absolute interferometers with the required sensitivity.

Dynamic Length Comparisons

During the period of development of precise absolute length measuring equipment discussed above, frequent measurements with precision of 0.2 ppm were required of a large number of test specimens. It was predicted that 50 measurements per week would be necessary. Absolute length-measuring interferometers have neither the precision nor testing capacity necessary for this task.

For use in this accelerated program, consideration was given to the interference comparator shown schematically in Fig. 5. This instrument is a development from the gage block comparator conceived in Germany just prior to World War II.[4] The present instrument would be precise to about 0.1 ppm, but the one instrument would have insufficient testing capacity. Reliance would be placed on comparison of static lengths, and this would be time consuming because thermal equilibrium would be required. For test specimens 2-in. long, a minimum of 4 hr would be necessary between the operation of wringing the test specimen to the platen and the comparison of this specimen with the primary master gage block. However, it can be used in the program on a limited basis to compare selected test specimens (secondary masters) with the primary master gage block, as described below.

Because absolute measurements of the primary master (the 2-in. control block discussed above) were initiated in 1954, and since 33 measurements were made at irregular intervals between that time and Dec., 1957, it was believed that its stability could be determined to a much greater precision than individual absolute measurements indicated. In fitting a curve to the above measurements, it became obvious that a cyclic function with a yearly period best fitted the measurements. Using Jan. 1, 1954, as a zero time reference, a curve calculated by the least-squares method to fit the measurement data is expressed by the equation:

$$L = \left[A \sin\left(\frac{2\pi t}{B} + \phi\right) + Ct + D\right]$$

where:

L = length deviation from nominal size (2 in.), microinches,
A = 0.75 in.,
B = 12 months,
t = time of measurement, months, (Jan. 1, 1954 = 0),
ϕ = 1.19π,
C = +0.0035 in. per month,
D = +4.59 in.

The standard deviation of all measurements from this curve was 0.28 microinch, with the largest variation for a single measurement being 0.5 microinch. Length measurements made since 1957 are in agreement with values predicted by this curve. It was assumed that the instability of this gage block is expressed by the function! $\Delta L = C\Delta t$, whereas, the sinusoidal variation is an effect due to error in determination of the effective temperature of the gage block.

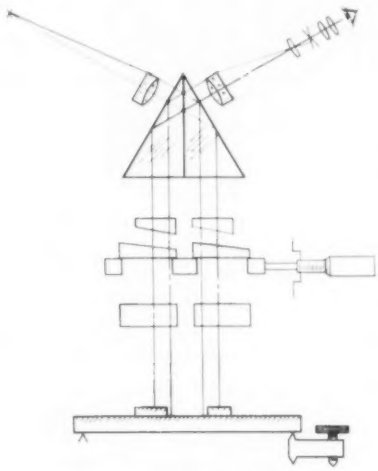


Fig. 5.—Elements of a gage block comparison interferometer.[4]

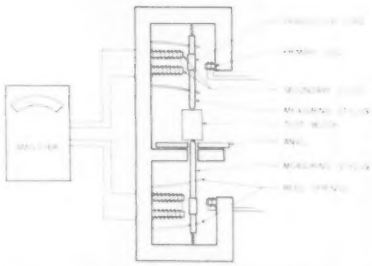


Fig. 6.—Elements of the mechanical comparator of lengths.

The most apparent solution to the problem of increasing test capacity was partially to abandon static length comparisons and replace them with dynamic length comparisons. These comparisons are called dynamic because of the handling and transportation of the test pieces just prior to measurement, which usually causes growth or shrinkage due to change of thermal conditions.

In general, however, dynamic comparisons had not been refined to give the required precision. It was questionable whether the mechanical comparators to be employed would provide the necessary repeatability. Figure 6 shows schematically the mechanical comparator used for comparing specimen lengths. The styluses are mounted in reed springs to avoid binding that can occur in bushing mountings. Transducers convert movement of the styluses into electrical signals that are amplified and activate a milliammeter. The signals from the top and bottom transducers are balanced so that translation of the test specimen in the direction of thrust of styluses has no effect upon the combined signal. This reduces the need for critical seating of the specimen upon the anvil.

In determining whether dynamic comparisons would provide the necessary precision, it was necessary to distinguish errors in comparison caused by lack of control of the dynamic effects from those due to the inherent randomness of the measuring instrument. The former could possibly be reduced to acceptable limits, whereas the latter would establish the limit of precision that could be obtained with available instrumentation.

It was found that to eliminate the dynamic changes, the comparison of test specimens would be required under conditions that restricted temperature variations of the specimens to less than 0.02 F. This seemed impractical. It was therefore decided to attempt to nullify dynamic changes in the comparison. If test specimens to be compared could be treated identically during the comparison and if the specimens responded to thermal variations in an equal manner, it was reasoned that dynamic changes of length could be nullified. Therefore, the test specimens were divided into groups, all blocks in a group having similar thermal properties. One block of each group was selected as a secondary standard. As the secondary standard in general would have thermal characteristics different from the primary standard block, it was planned to compare the secondary standards with the primary standard by using the interference comparator (Fig. 5). The secondary standards would then be used in dynamic comparisons with test specimens in their respective groups using the mechanical comparator.

Conventionally, the secondary standard would be compared with each test specimen in its group. This technique, however, gives special emphasis to the test specimen that has been designated as a secondary standard and thus violates the requirement of equal handling of all test specimens to nullify dynamic changes occurring during the comparisons. A more appropriate comparison technique is one that has occasionally been employed at the Bureau. In this system the secondary standard is handled as one of the test specimens of the group. All possible comparisons of specimens within the group are made to form one intercomparison test. The comparison data are reduced in

[4] T. R. Young, "Achromatic Interferometer for Gage Block Comparison," *NBS Circular 581*, Nat. Bureau Standards, p. 43, April, 1957.

such a way that the average length of each block in the group is obtained relative to the average length of all blocks of the group. Comparing these average values provides calculated results of the length difference between any pair of blocks in the group. The calculated results related to the actual measured data provide a series of residuals—in the current tests at the Bureau 110 residuals are obtained on eleven blocks in each intercomparison test. To some extent, the distribution of these residuals indicates the characteristics of the systematic error occurring in the intercomparison series. The fidelity of this indication depends upon the degree to which the effects of systematic error have been removed from the calculated results.

Locating Sources of Error

The reduction by least squares provides a calculated value for each comparison. The residual, or the difference between the calculated and observed values, is used to determine the probable precision of results by plotting the magnitude of each residual against the number of times it occurred. These frequency distributions served as a powerful tool in developing a satisfactory measuring technique, precise to 0.2 microinch. They have been used to establish the relationship between calculated probable error and the precision actually realized, to eliminate bias from comparison procedures, and to locate sources of systematic error.

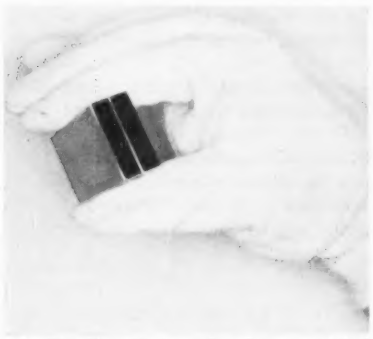
For example, residual frequency distributions have been very effective in prescribing handling procedures for a two-block test set. An operator can handle blocks manually with greater ease and assurance than with tongs or other tools that introduce the danger of dropping. Using insulating gloves, the operator would pick up two blocks simultaneously by their nongaging faces and place them in the comparator in what was considered symmetrical handling. However, it was soon revealed that the manner in which the blocks were held had a significant effect on the symmetry of the residual frequency distributions. It was concluded that handling was producing an asymmetrical thermal effect—the blocks were held so that one was nearer the operator's palm than the other (Fig. 7(*a*). After the procedure was changed so that blocks were picked up in tandem with their nongaging faces toward the palm (Fig. 7(*b*)), the statistical distributions showed the expected symmetry.

Starting with the simplest and most convenient comparison procedures and sequences, the general method used in refining the comparison technique was first to hypothesize, from the residual distributions obtained, the nature of the systematic and random errors. Then, when possible, the sequence of the comparisons was changed in an attempt to nullify the systematic error in the calculated results. An indication of the correctness of the hypothesis and of the change of sequence of comparisons was obtained when the residuals changed their distribution so as to be consistent with the hypothesis of the nature of the error. The next step was to make use of a knowledge of the probable nature of the systematic error, and scrutinize the comparison procedures for a possible source of error. Effective removal of the source would in turn be indicated when the residuals assumed the form of more random distribution, as illustrated in Fig. 8.

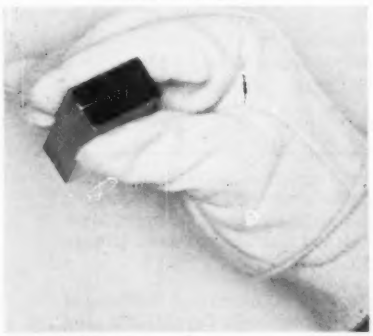
The results obtained at the Bureau indicate that mechanical length comparators can be used for measurements with a precision approaching 0.2 microinch. The procedures involved are applicable to the relatively rapid measurement of a large number of parts when these have the same nominal size and thermal properties. These procedures should therefore be adaptable to industrial control applications. The use of automated equipment should enhance the probability of nullification of dynamic effects. Statistical analysis, used in conjunction with the comparison procedures, has application in determining the most suitable methods and in providing continued uniformity in the application of the techniques. The reduction of the measurement data can be accomplished with electronic computing equipment. In approximately 30 sec, one such machine can reduce the data and determine the distribution of residuals obtained in an intercomparison of eleven test specimens.

Summary and Conclusions

1. A program has been described for the development of steel gage blocks with a maximum dimensional change of 0.2 microinch per in. per yr, a degree of stability heretofore un-

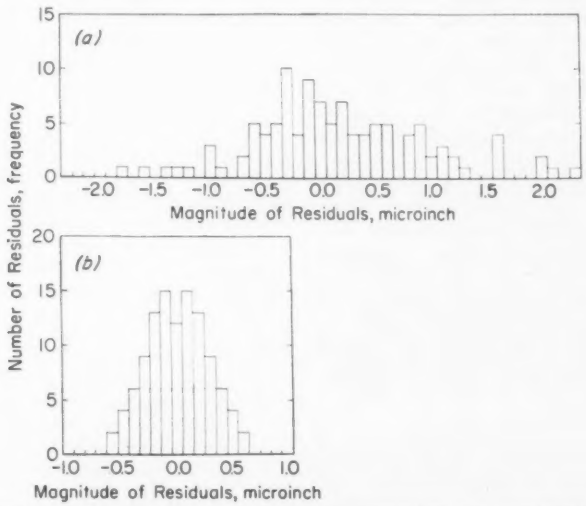


(*a*)—Handling that produced asymmetrical thermal effect.



(*b*)—Modification used to correct asymmetrical condition.

Fig. 7.—Manner of handling two gage blocks for comparison measurement.



(*a*)—Typical distribution obtained from an intercomparison test conducted during the initial development phase of the measuring technique.
(*b*)—Typical distribution obtained from an intercomparison test conducted during a more advanced development phase of the measuring technique.

Fig. 8.—Examples of frequency distributions of residuals obtained in two intercomparison tests.

obtainable with consistency. The problem was twofold, since procedures for the selection and processing of materials, and suitable techniques for measurement to the desired precision were developed simultaneously. The 1-yr period of observation provides a favorable outlook on future performance, but past experience has shown that variations may occur.

2. The data presented are the result of observations for 1 yr on two steels (410 stainless and 52100) given a total of 14 treatments. Blocks made from these two steels represent only a small proportion of those under development or observation. Two treatments applied to 410 stainless steel produced gage blocks with an average dimensional change, uniform in time, of 0.2 microinch per in. per yr. One treatment applied to the 52100 steel produced gage blocks with an extremely high degree of stability (0.1 microinch per in. per yr) after an initial less-stable period of 6 months. Although the results indicate that the goal of the investigation may have been met, periods of observation greater than 1 yr are needed to corroborate the stability characteristics. Further improvements in the development of materials and measuring techniques seem possible and will be sought. The failure of other treatments of the 410 and 52100 steels to produce equally stable gage blocks in those cases where the treatments were similar except for small modifications, such as direction of grinding or thickness of nitrided case, has suggested other courses of investigation which are being pursued. Other more subtle influences on stability are being studied also, such as influence of residual magnetism (induced by magnetic grinding chuck) and environmental temperature changes.

3. The method of reporting changes in length in microinches per inch is a matter of convention and convenience and should not be construed as being directly convertible to any size of gage block, particularly those of less than 1 in. Size effects can influence both the metallurgical and metrological factors, and consideration is being given to the investigation of these effects.

4. Mechanical comparators can be used for measurements with a precision approaching 0.2 microinch. The procedures involved are also applicable to the rapid measurement of a large number of parts of the same nominal size and thermal properties, and therefore can be adapted to industrial applications. Statistical analysis, used in conjunction with the comparator techniques, has application in determining the most suitable procedures and providing continued uniformity in the application of the technique.

Compression Testing of Gypsum Plaster

By E. H. WATERS and R. BIRTWISTLE

Tests on six commercial plasters show that to obtain a value for compressive strength within ±5 per cent of the true mean (95 per cent confidence limits) usually three separate batches of cubes must be tested. From one batch the value will normally lie within ±8 per cent of the true mean. Increasing the number of cubes per batch above five does little to improve the precision. Machine mixing shows little or no advantage over hand mixing, and it appears that much of the "between-mix" component of the variance is due to the testing phase despite the use of a pacing disk to control rate of platen movement.

Compressive strength was found to rise with increased time and increased rate of stirring and to be an approximately linear function of the fluidity of the slurry.

Specimens tested wet (2 hr after casting) had on the average 40 per cent of the strength of those tested dry, but despite the obvious advantages of 2-hr testing care must be exercised in its use because of the different rates of strength development of plasters with similar setting times.

As with all mechanical tests for the strength of materials the compressive strength of gypsum plasters is subject to random variation, and hence a number of specimens must be tested in order to obtain a reliable figure.

ASTM Methods of Testing Gypsum and Gypsum Products[1] call for six 2-in. cubes to be cast from one mix, moist-cured for 24 hr, dried to constant weight at a relative humidity not greater than 50 per cent, and then stored for 24 hr over anhydrous calcium chloride before testing. Standards Association of Australia Interim Specification 317: Gypsum Plaster, Hemihydrate Type (SAA Int. 317), is similar except that five 1-in. cubes are used and the storage over calcium chloride is omitted.

Experience in the Division of Building Research and elsewhere had shown that the results of repeated tests carried out under these conditions were often subject to considerable scatter, and it appeared desirable to investigate some of the variables of this test in order to find out whether it would be practicable to reduce this scatter.

Previous workers have shown that the strength of gypsum plasters is greatly reduced by the presence of very small amounts of free water, and that once the free-water content reaches about 2 per cent the strength is practically that of the saturated specimens (1,2).[2] It has also been found that the strength of oven-dried specimens (40 C) falls rapidly when they are exposed to the laboratory atmosphere, presumably because of the adsorption of atmospheric moisture (3).

Partly because these findings sug-

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[1] 1958 Book of ASTM Standards, Part 4, p. 297.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

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gested that less scatter should be observed if specimens were tested wet, and partly because of this Division's interest in load-bearing gypsum plaster (where wet-strength figures are necessary for design purposes), it has become customary to test wet, usually 2 hr after casting.

This period was chosen because early tests on local plasters (initial setting times 20 to 30 min) showed little or no increase in wet strength after 2 hr; for slower hydrating plasters a correspondingly longer period would be necessary. Two-hour testing has obvious advantages in mill control because of the reduced delay in obtaining results, and also in the manufacture of large precast gypsum walls because it corresponds closely with the actual strength of the units at the time they are lifted from the casting tables. However, no systematic investigation of the relationship between this wet strength and the dry strength laid down in standard specifications had been made, nor had the effect on the variability of the test results of wet testing as compared to dry testing been examined.

The work reported here was therefore designed to investigate these questions and, in addition, to explore the effects on variability of machine and hand mixing, and to determine the number of mixes and specimens necessary to obtain a given degree of precision in the final strength figure. The effect of variations in consistency of the plaster mix on the strength was also investigated because the consistency specified in SAA Int. 317 had been criticized as unrealistic, and hence some idea was needed of the effect on strength of the difference between laboratory and works consistency.

Materials

Six brands of commercial hemihydrate plaster chosen as representative of the plasters manufactured in the Southeastern States of Australia were used for this work. They are designated A, B, C, D, E, and F.

The water:plaster ratios required to produce the various consistencies used in these tests and the setting times of the plasters at these consistencies are shown in Table I.

One bag of each plaster was emptied into containers with tightly fitting press-in lids and stored thus for the duration of the experiments. This constituted a batch of the particular plaster; where a further batch is mentioned the same procedure was followed with a fresh bag of the same make of plaster.

Experimental Procedure

Setting Times

Initial Set.—This was considered to be complete when a $\frac{1}{8}$-in. (3-mm) lead shot dropped from a height of 9 in. (23 cm) just penetrated the plaster to its diameter. The advantages and precision of this method are to be discussed elsewhere. This method gives a setting time appreciably shorter than that given by the Vicat needle test of ASTM Method C26 (by about 10 min on plasters having a lead-shot setting time of between 20 and 30 min), but corresponding closely to the time after which the plaster cannot be cast with ease or without serious loss of strength.

Final Set.—The set was considered to be complete when the temperature of the mix reached a maximum. Consistencies were measured by the method of SAA Int. 317, that is, a cylinder 2 in. (51 mm) high and $1\frac{3}{8}$ in. (35 mm) in diameter resting on a clean glass plate is filled with the plaster mix and then quickly lifted clear. The diameter to which the resultant pat of plaster spreads is then measured.

Plaster Cubes

Preparation.—Except as outlined below the general procedure of SAA Int. 317 was followed unless the contrary is specifically stated. This procedure is generally similar to that of ASTM Method C 26 except for (1) the sample size (occasioned by the smaller specimens), (2) the use of neat instead of sanded plaster, (3) a mandatory time of 15 sec for adding plaster to water, and (4) a soaking time of 30 sec instead of 2 min.

To allow for the greater number of cubes per mix the sample size was doubled (300 g plaster instead of 150 g except where some other quantity is specifically stated).

Instead of the plaster being shifted into the water it was sprinkled from a scoop as evenly as possible (sifting was found to take much more than the allotted 15 sec, even when a 10-mesh sieve was used).

For all except plasters A and E it was found at the stiffest (No. 1) consistency that the prescribed soaking time of 30 sec was insufficient to permit all of the plaster to become wet. The average soaking times required at consistency No. 1 were:

Plaster	Average Soaking Time, sec
A	less than 30
B	50
C	45
D	85
E	less than 30
F	45

At all other consistencies less than 30 sec was necessary for all the plasters. Tests made with plaster D using (1) the standard 30-sec soak, and (2) soaking until no dry plaster was visible (six sets of four cubes at each condition) gave a higher grand mean and a narrower spread of batch means for the fully soaked plaster (720 psi and 650 to 810 psi, as against 680 psi and 630 to 825 psi). In consequence those plasters that were not fully soaked in 30 sec were, in all subsequent tests, allowed to soak until no dry plaster remained visible.

Mixing was carried out either by hand or machine as noted under the appropriate experiments. Hand mixing was performed with a flat spatula 2 cm wide in a rubber bowl of 1.4 liter capacity. The speed of hand mixing was controlled by an audible signal, the pace of which could be varied at will. Except where otherwise noted, hand stirring was at a standard speed of 192 spatula revolutions per min.

Machine mixing was either in a Hobart mixer as described in ASTM

TABLE I.—WATER:PLASTER RATIOS AND SETTING TIMES OF PLASTERS.

Consistency	No. 1			No. 2			No. 3			No. 4			No. 5		
Spread Diameter, in.	4			5			6			7			8		
Plaster	$\frac{W}{P}$[a]	I.S.[b]	F.S.[c]	$\frac{W}{P}$[a]	I.S.[b]	F.S.[c]	$\frac{W}{P}$[a]	I.S.[b]	F.S.[c]	$\frac{W}{P}$[a]	I.S.[b]	F.S.[c]	$\frac{W}{P}$[a]	I.S.[b]	F.S.[c]
A	0.64	29	61	0.69	31	63	0.75	32	63	...	...	...	...	...	...
	0.63	29	63	...	...	...	0.73	33	66	...	...	...	0.88	36	66
B	0.61	13	47	0.66	14	48	0.72	15	48	0.79	19	51	0.90	20	49
C	0.56	20	61	0.61	22	62	0.66	25	65	0.72	28	67	0.81	28	65
D	0.60	23	61	0.65	24	60	0.71	28	64	...	...	...	...	...	...
E	0.64	9	39	0.69	10	38	0.75	11	39	0.82	11	39	0.94	13	38
F	0.66	39	88	0.72	41	88	0.79	46	89	...	...	...	...	...	...

[a] $\frac{W}{P}$ = water:plaster ratio.
[b] I.S. = initial set, min.
[c] F.S. = final set, min.

TABLE II.—PLASTER QUANTITIES AND MIXING CONDITIONS FOR THE EXPERIMENTS ON THE EFFECT OF MIXING SPEED ON STRENGTH.

Treatment, rpm	Plaster, g[a]	Water, ml	Adding Time, sec	Soaking Time, min	Mixing Time, min
HAND-MIXED					
60	300	210	15	1	2
120	300	210	15	1	2
200	300	210	15	1	2
MACHINE-MIXED					
120	300	210	15	1	2
200	500	350	30	1	2
300	750	525	40	1	2
400	1250	875	50	1	2
500	1500	1050	60	1	2
600	2250	1575	60	1	2

[a] Plaster B, batch 2, consistency No. 3 (spread diam. 6 in.).

were kept over water in a closed vessel.

Cubes tested after rewetting were dried as for dry testing and then immersed in water for approximately 20 min before testing.

The initial experimental plan called for the testing of each of the six plasters (1) after 2 hr (that is, wet); (2) dry; and (3) rewetted after drying, with cubes made at three consistencies by both machine (Hobart mixer) and hand mixing. For plaster A, eight batches of twelve cubes each were made in random order for each consistency and method of mixing (for example, hand-mixed plaster at consistency No. 3 consisted of batches 7, 11, 19, 30, 38, 39, 46, and 48), making a total of 48 batches (576 cubes). Since the molds were constructed in gangs of four, one of these four-piece molds was chosen at random from each three for testing at 2 hr. The remaining eight cubes were dried, and four chosen at random were tested in this condition and the remaining four after rewetting.

TABLE III.—COMPRESSIVE STRENGTHS AND VARIABILITY OF SIX PLASTERS AT FIVE CONSISTENCIES (psi).

			Consistency 1, 4-in. Spread		Consistency 2, 5-in. Spread		Consistency 3, 6-in. Spread		Consistency 4, 7-in. Spread		Consistency 5, 8-in. Spread	
Plaster	Mixing[a]	Testing[b]	Grand Mean	Coefficient of Variation	Grand Mean	Coefficient of Variation	Grand Mean	Coefficient of Variation	Grand Mean	Coefficient of Variation	Grand Mean	Coefficient of Variation
A, first experiment	H	W	770	7.7	648	6.4	556	5.4	...	...	...	...
	M	W	756	8.9	639	6.9	527	8.3	...	...	...	...
	H	D	1751	8.2	1479	10.0	1245	13.9	...	...	...	...
	M	D	1580	17.0	1438	13.9	1204	9.1	...	...	...	...
	H	R	750	6.7	622	7.5	506	6.0	...	...	...	...
	M	R	708	9.0	615	6.2	503	7.8	...	...	...	...
A, second experiment	H	W	779	4.5	...	...	542	5.4	...	...	359	5.4
	H	D	1829	3.5	...	...	1308	3.7	...	...	847	4.7
	H	R	791	3.8	...	...	528	3.7	...	...	352	4.9
B	H	W	623	6.2	476	5.1	364	6.0	284	7.4	198	5.9
	M	D	1798	4.7	1434	5.9	1099	11.4	827	9.1	588	6.4
	H	R	787	6.6	603	5.8	464	8.4	365	7.7	264	3.9
C	H	W	884	5.1	678	4.6	588	4.4	467	5.9	364	5.9
	H	D	2143	3.4	1748	5.9	1545	5.6	1207	7.2	949	6.2
	H	R	812	5.1	645	4.8	558	5.9	442	6.5	327	4.1
D	H	W	679	7.2	602	9.0	492	5.5	...	...	...	...
	M	W	688	10.4	573	4.8	446	6.2	...	...	...	...
	H	D	1779	4.4	1525	3.2	1236	6.6	...	...	...	...
	M	D	1727	6.2	1438	4.4	1145	5.4	...	...	...	...
	H	R	694	6.9	611	9.0	485	8.8	...	...	...	...
	M	R	696	9.8	592	5.7	446	4.4	...	...	...	...
E	H	W	760	3.7	644	4.6	529	5.1	429	4.4	325	3.0
	H	D	1902	4.2	1623	5.5	1349	5.2	1083	4.1	837	3.2
	H	R	792	3.3	644	5.3	531	5.2	435	2.8	330	4.9
F	H	W	503	4.0	410	11.2	366	4.5	...	...	...	...
	M	W	520	7.5	407	7.3	345	9.0	...	...	...	...
	H	D	1271	4.1	1081	6.2	902	7.3	...	...	...	...
	M	D	1295	5.1	1035	4.9	887	9.3	...	...	...	...
	H	R	503	5.9	406	9.2	345	8.6	...	...	...	...
	M	R	519	7.2	409	5.2	409	6.5	...	...	...	...

NOTE.—Four batches of four specimens tested at each consistency, except 8 batches for plaster A, first experiment.
[a] H = Hand mixed. M = Machine mixed (Hobart mixer).
[b] W = Tested wet (2 hr after casting). D = Tested dry. R = Tested after drying and rewetting.

Method for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency (C 305–59 T)[3] (except that the speeds available were different) or in the special de-airing mixer described by Hiraki, Asada, and Okamoto (4). The Hobart mixer was used at 192 rpm with a hook stirrer modified to fit the profile of the rubber bowl that was used for hand mixing The de-airing mixer of Hiraki, et al, resembles a domestic food mixer of the bottom-driven "vitamiser" type, but is fitted with a single flat paddle instead of the usual propeller-type blade and a stainless steel bowl, and could be operated through a constantly variable speed drive at speeds of from 120 to 600 rpm.

[3] 1958 Book of ASTM Standards, 1959 Supplement; Part 4, p. 13.

Every care was taken to keep the cubes poured from each mix as uniform as possible by filling each mold in several steps and by pouring into the various molds at random at each step of the filling.

Testing.—All cubes were tested in a Baldwin universal testing machine at a nominal rate of platen movement of 0.2 in. per min (as determined by a pacing disk) in a room conditioned to 21 C and 50 per cent relative humidity. Where cubes are stated to have been tested dry they were dried to constant weight at 38 to 40 C and then exposed to the laboratory atmosphere for 15 min before testing.

Cubes tested wet were kept in the mold until just before testing, and if the period was greater than 1 hr the molds

After these results were analyzed the number of batches for each combination of conditions was reduced to four that is, 288 cubes for each plaster. After three plasters (A, D, and F) had been treated in this way analysis of the results showed no significant difference in variability between hand- and machine-mixed batches. The use of the Hobart mixer was therefore discontinued, and the opportunity was

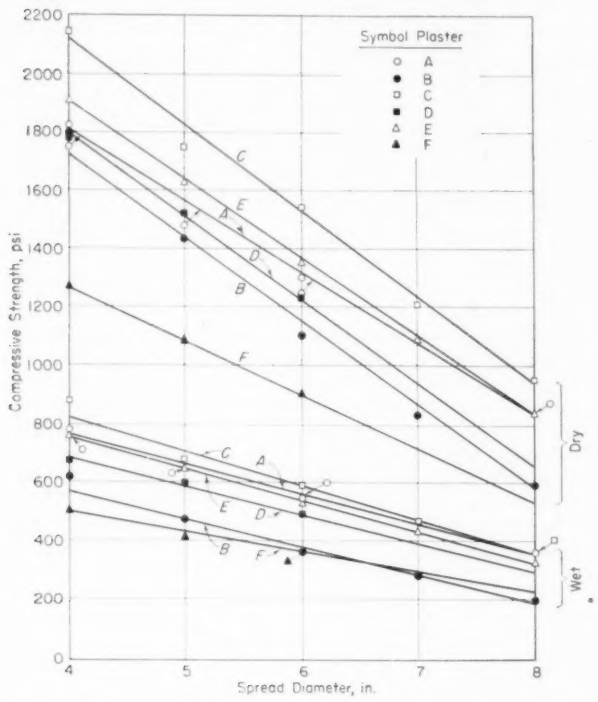
taken to extend the range of consistencies to five (see Table I), that is, 240 cubes per plaster.

After a lapse of six months plaster A was retested (hand mixing only) at consistencies 1, 3, and 5 partly to check on any change which may have occurred during storage and partly to extend the range of consistency data (experiment No. 2 of Table III).

and the remaining four were weighed and measured to determine the density of the dry-set plaster. The latter specimens were also tested after they had remained in the laboratory atmosphere (unconditioned) for between seven and nine weeks. Because of a tendency of the Hiraki mixer to form a vortex at high speeds with small charges and its inability to stir large charges

mixer of the Hobart type instead of mixing by hand.

The relationships between wet (2 hr) and dry strengths and consistencies for the six plasters are shown in Fig. 1. The curves of this figure are calculated linear regression lines from the data for hand-mixed specimens; the plotted symbols are the actual experimental values. The regression lines for plaster A have been derived from the data of the second experiment only because of



An arrow, if directed to another symbol, indicates coincident points; if directed to a regression ine, indicates that the point as plotted belongs to the plaster for which the code letter appears on the indicated line.

Fig. 1.—Relationship of compressive strength to the consistency of the mix: experimental values and calculated linear regression lines.

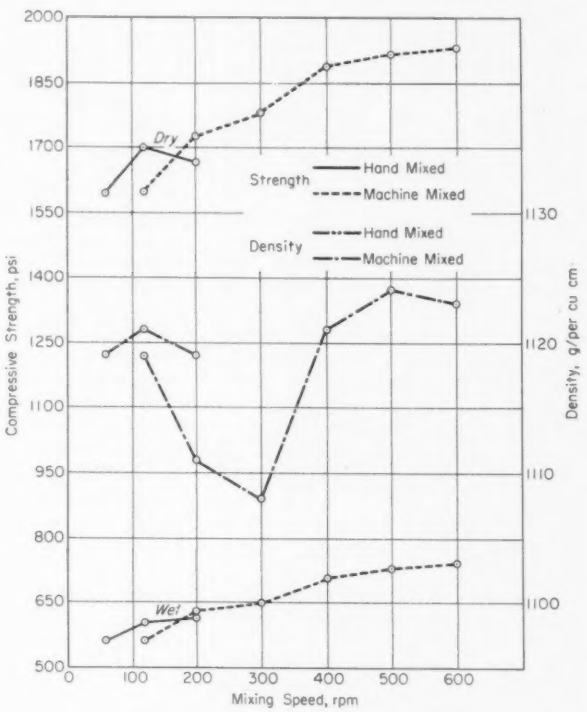


Fig. 2.—Effect of mixing speed on strength and density of plaster B.

The mixer described by Hiraki, et al, was claimed by them to reduce both the size and number of bubbles of entrained air and to increase the strength of the resultant casts. In case part of the variability observed was due to differential entrainment of air by conventional mixing methods, a portion of the experiments of Hiraki, et al, was repeated with a sufficient number of replications to enable the variation to be studied. These tests were made with one plaster only (a second batch of plaster B) and at one consistency, but speeds were varied over the full range of the machine. Simultaneously, hand mixes of the same plaster were prepared at three speeds, namely, 60, 120, and 200 rpm. Four mixes of twelve cubes each were prepared in random order for each combination of hand and machine mixing and speed. One set of four was tested wet (2 hr) the remainder dried, four selected at random were tested,

efficiently at low speeds, it was necessary to vary the quantities used at the various speeds (see Table II).

Results and Discussion

The results of the tests on the six plasters at various consistencies, using both hand mixing and the Hobart mixer, are summarized in Table III. It can be seen from the table that although nearly half the batches showed coefficients of variation between 2.8 and 5.5 per cent there was a wide range of variability with coefficients of variation ranging up to 17.0 per cent. No significant differences could be shown between the variabilities of the hand- and machine-mixed batches. In the few cases where there was a significant difference in strength the hand-mixed specimens were the stronger. It appears therefore that no advantage can be obtained by using a

the high variability of the data from the first, although the experimental points from both have been plotted. It is noticeable that only those for the dry specimens of the first experiment (where the variability was greatest) show any marked departure from the calculated line, and that these are all low. No significant departure from linearity could be detected for the relationship between consistency and the dry strength of any of the six plasters or the wet strengths of plasters D, E, and F. A departure from linearity could be detected for the wet strengths of plasters A, B, and C, but only at the 5 per cent level and in the case of plaster C mainly because of one point. Linear regression curves have therefore been drawn for all plasters.

The relationship has been expressed as strength versus spread diameter rather than strength versus water:

TABLE IV.—EFFECT OF STIRRING SPEED ON STRENGTH.[a]

Mixed in Hiraki Machine						
Stirring speed, rpm	120	200	300	400	500	600
Strength, wet (2 hr), psi	554	628	647	706	731	739
Coefficient of variation	8.3	6.2	7.9	4.1	3.0	2.6
Strength, dry (immediate), psi	1597	1723	1778	1884	1912	1926
Coefficient of variation	5.0	7.0	7.0	6.4	3.6	4.3
Strength, dry (after 2 months), psi	1376	1563	1603	1679	1719	1756
Coefficient of variation	6.3	5.8	4.2	4.8	3.9	3.0
Mixed by Hand						
Stirring speed, rpm	60		120		200	
Strength, wet (2 hr), psi	560		604		612	
Coefficient of variation	4.4		3.7		4.7	
Strength, dry (immediate), psi	1593		1697		1662	
Coefficient of variation	3.8		4.5		5.1	
Strength, dry (after 2 months), psi	1493		1516		1525	
Coefficient of variation	4.8		2.5		4.0	

[a] Plaster B, batch 2. All figures are means of four batches of four cubes each.

TABLE V.—EFFECT ON PLASTER STRENGTH OF VARYING BOTH SPEED AND TIME OF MIXING.[a]

Mixing Time, min	Mixing Speed, rpm 200	400	600
½	561	631	642
1	583	662	728
2	688	751	766

[a] Strengths shown are wet (2 hr), psi. Each value is the mean of two batches of four cubes each.

plaster ratio, for two reasons. First, plaster is normally used at some definite consistency which may vary with the manner of use but for a given use will be reasonably constant, and it is desirable to be able to compare the strengths obtained at standard laboratory consistency with those obtainable at field or plant consistencies. Secondly, the plot of strength versus water:plaster ratio is strongly curved, while that of strength versus spread diameter is linear or very nearly so, and hence interpolation and if necessary extrapolation can be much more easily carried out. Actually this is a plot of strength versus fluidity rather than consistency, since a high spread diameter means a low consistency, that is, high fluidity.

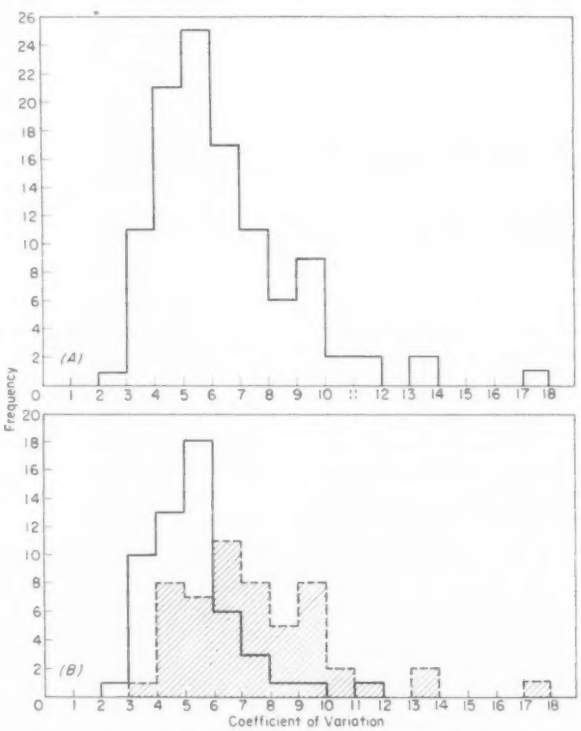
The results for the tests on plaster B (second batch) at various mixing speeds are shown in Fig. 2 and Table IV. From these it can be seen that there is, as Hiraki, et al, found, a considerable increase in strength as the speed of the mixer is increased, and even with hand mixing an appreciable change in strength with speed is apparent. Although the coefficients of variation show some rather erratic behavior there is over-all a significant decrease in the coefficient of variation as the mixing speed is increased. No significant difference in variability could be demonstrated, however, between the mixes prepared in this machine and those prepared by hand mixing at the same speeds.

Although the Hiraki machine appeared by visual inspection to produce, with increasing speed of mixing, the de-airing claimed for it (see Fig. 5) there was no apparent correlation between density and speed or between density and strength (see Fig. 2).

When the cubes that had been used for the density measurements were tested for compressive strength after exposure for approximately two months to the atmosphere of an unconditioned room they showed a general decrease in strength of the order of 10 per cent, together with a somewhat smoother decrease in the coefficient of variation as the mixing speed increased. This suggests that part of the variability observed with specimens tested 15 min after leaving the drying chamber may result from the fact that they are not in equilibrium with the atmosphere and are still changing relatively quickly. After long standing in the atmosphere the specimens are probably changing much more slowly, even though the storage area is not air conditioned.

When the time for which the plaster was mixed was varied, as well as the speed of mixing, the results of Table V were obtained. From these data it is apparent that changes in mixing time have, in general, much less relative effect on strength than changes in speed.

If the strengths obtained with wet (2 hr) and dry specimens are compared (see Tables III and VI) it will be seen that there is, in general, an approximate ratio of 0.40 between them and that this applies at all consistencies. The major departures from this generalization are plasters A and B, in which the ratios are 0.44 and 0.34, respectively. If the results for rewetted specimens are used instead of those for the 2-hr test, the ratio for plaster B rises to 0.43 while all others either remain constant or fall slightly. This suggests that plaster B had not attained its maximum wet strength at 2 hr although the other plasters apparently had done so. To confirm this, tests were made ranging in time from 1 to 25 hr after casting. Unfortunately the stock of plaster A was exhausted, and insufficient amounts of



(*a*) All values from Table III.
(*b*) Values from the first and second halves of the experiments of Table III plotted separately. First half (dotted outline, hatched): plasters A (first experiment), D, and F. Second half (solid outline): plasters A (second experiment), B, C, and E.

Fig. 3.—Distribution of coefficient of variation.

plaster B remained to complete the series. However, it is apparent from the results given in Table VII that plasters C, D, E, and F had all reached their maximum wet strength by 2 hr (E by 1 hr), but plaster B was still gaining strength between the 3-hr and 5-hr tests despite the fact that it was much faster setting than plasters A, C, D, and F. It is of interest that plaster C, which showed a lower ratio of rewetted to dry strength than of 2-hr to dry strength, shows a marked drop in strength between 7 and 25 hr, the latter strength being not significantly different from its rewetted strength.

It appears therefore that short-time wet testing, although satisfactory for most of the plasters examined here, can give misleading results with some plasters that develop strength slowly. Since all of the plasters were essentially calcium sulfate hemihydrate the reason why plaster B developed strength so much more slowly than the rest is not known, nor is it known why the strength of plaster C deteriorated so much when rewetted or kept wet for 25 hr. (It is well known that plasters lose strength when kept wet for long periods, but apparently this change takes place much more rapidly in plaster C than in most other plasters.)

When the data of the original tests summarized in Table III were analyzed it was found that in most cases the variation between mixes was greater than the variation within mixes. Hence any estimate of the mean strength obtained from a number of specimens made from a single mix is likely to be biased, and furthermore, any statement of statistical confidence attached to this limit will give an underestimate of the likely range of values. This means that any later estimate of the mean (made, of course, from a new mix) will have a greater probability of falling outside the calculated confidence limits than would be expected. The results of these analyses are summarized in Table VIII in the form of estimates of the number of mixes and cubes per mix that would be required so that the 95 per cent confidence limits for the mean will fall within (*a*) ±5 per cent. or (*b*) ±10 per cent of the observed mean at several representative values of the coefficient of variation. The range of the 95 per cent confidence limits with the present method of testing five cubes from one mix is also given.

One of the most striking features of this investigation has been the wide range of variability found. Since the utmost care had been taken in the preparation of the specimens, and mechanization of the mixing procedure had failed to reduce the variability, it was suspected that the fault might lie in the testing procedure. Examination of the testing machine records showed that a relatively new operator had taken over shortly before this investigation began, and that during the tests summarized in Table III (which were spread over about six months) four relieving operators had also carried out some of the testing. However, all five were considered to be competent testing machine operators, and since the machine was operated at a fixed rate of platen movement by means of a pacing disk no trouble had been expected from this source. Examination of the coefficients of variation (C.V.) for the various operators showed that at the start of the investigation the new regular operator was giving a much higher C.V. than the relieving operators, but by the end of six months, when the first plaster was retested, this

TABLE VI.—RATIOS OF WET AND REWETTED STRENGTHS TO DRY STRENGTH.

Plaster	Consistency					
	No. 1	No. 2	No. 3	No. 4	No. 5	Mean
A, first experiment:						
Wet	0.44	0.44	0.44	...	...	0.44
Rewetted	0.43	0.42	0.40	...	...	0.42
A, second experiment:						
Wet	0.43	...	0.42	...	0.42	0.42
Rewetted	0.43	...	0.41	...	0.41	0.42
B: Wet	0.35	0.33	0.33	0.35	0.34	0.34
Rewetted	0.44	0.42	0.42	0.44	0.45	0.43
C: Wet	0.41	0.39	0.38	0.39	0.39	0.39
Rewetted	0.38	0.37	0.36	0.37	0.34	0.36
D: Wet	0.38	0.39	0.40	...	...	...
Rewetted	0.39	0.40	0.39	...	...	...
E: Wet	0.40	0.40	0.39	0.40	0.39	0.40
Rewetted	0.42	0.40	0.39	0.40	0.40	0.40
F: Wet	0.40	0.38	0.41	...	...	0.40
Rewetted	0.40	0.38	0.38	...	...	0.39

TABLE VII.—EFFECT OF TIME ON WET STRENGTH OF PLASTERS, PSI.

Plaster	Testing Time, hr from casting						
	1	2	3	5	7	25	R[a]
B	225	...	540	570	...	...	526
C	624	742	744	744	758[b]	714	706
D	218	568	570	566	564	572	562
E	618	619	628	622	624	634	609
F	416	480	485	460	481	474	446

[a] Rewetted, that is, dried after 24 hr damp storage and then rewetted before testing.
[b] Values underlined do not differ at the 5 per cent level of significance.

TABLE VIII.—RELATION BETWEEN NUMBERS OF MIXES AND NUMBER OF SPECIMENS PER MIX AND PRECISION AT VARIOUS VALUES OF THE COEFFICIENT OF VARIATION.

Number of Specimens per mix	Number of Mixes									
	C.V. = 4 per cent $S_m^2/S^2 = 0.5$		C.V. = 5 per cent $S_m^2/S^2 = 1.5$		C.V. = 6.5 per cent $S_m^2/S^2 = 3.5$		C.V. = 8 per cent $S_m^2/S^2 = 4$		C.V. = 10 per cent $S_m^2/S^2 = 4$	
	M5[a]	M10[b]	M5[a]	M10[b]	M5[a]	M10[b]	M5[a]	M10[b]	M5[a]	M10[b]
1	3	1	4	1	7	2	11	3	16	4
2	2	1	4	1	6	2	10	3	15	4
3	2	1	3	1	6	2	9	3	14	4
4	2	1	3	1	6	1	9	3	14	4
5	1	1	3	1	6	1	9	3	14	4
6	1	1	3	1	6	1	9	3	14	4

[a] M5 = number of mixes for it to be 95 per cent certain that the mean obtained lies within ±5 per cent of the "true" or population mean.
[b] M10 = number of mixes for it to be 95 per cent certain that the mean obtained lies within ±10 per cent of the "true" or population mean.

TABLE IX.—VARIABILITY TESTS ON PLASTER A, BATCH 2.[a]

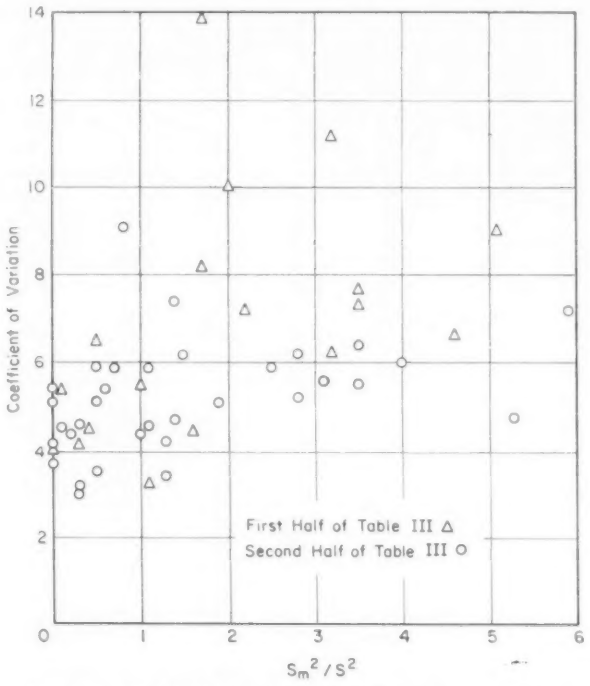
Testing Condition	Wet (2 hr)	Wet (5 hr)	Dry	Rewetted
200 g plaster per mix, 16 mixes:				
Mean strength, psi	654	611	1450	576
Coefficient of variation, per cent	4.1	4.3	4.5	3.9
500 g plaster per mix, first 8 mixes:				
Mean strength, psi	643	594	1512	580
Coefficient of variation, per cent	5.7	5.0	3.0	4.1
500 g plaster per mix, second 8 mixes:				
Mean strength, psi	608	572	1418	554
Coefficient of variation, per cent	4.4	5.3	4.9	2.8
500 g plaster per mix, 12 mixes:				
Mean strength, psi	643	601	1454	572
Coefficient of variation, per cent	4.2	4.6	3.1	4.6

[a] Over-all coefficient of variation, 4.2 per cent.

operator's C.V. was lower than any of the others and averaged about 4.5 per cent.

A further series of specimens was then prepared and tested, using a fresh batch of plaster A. For these, the assistant who had previously made all the cubes—a conscientious man of considerable manual skill but no previous testing machine experience—was chosen to make and test all specimens. Sixteen mixes using 200 g plaster and 28 mixes using 500 g plaster were prepared (water:plaster ratio 0.70). From each mix four cubes were prepared and one tested at 2 hr, one at 5 hr, one after drying, and one after rewetting. The results are given in Table IX. From these it can be seen that a sufficiently careful operator can obtain results with a coefficient of variation of a little over 4 per cent, although it is apparent from the earlier experiments that this will not always be so. In Fig. 3, histograms have been drawn of the distribution of coefficients of variation given in Table III. Figure 3(*a*) shows the over-all histogram for the 108 values of C.V. Figure 3(*b*) shows superimposed the distributions of the first 54 values (representing 288 mixes) and of the second 54 values (representing 216 mixes). It is apparent that despite occasional values of 8 or more the distribution in the second half of the experiment was much narrower than in the first, with a marked peak between 5 and 6 and a considerable proportion of values below 5. It is not possible from the available information to determine how much of this reduction in variation was due to improved operation of the testing machine and how much to improved specimen-making technique. The differences in variability as between different operators mentioned above, and the lack of any significant reduction in variability when machine mixing was used instead of hand mixing shows that even with the rate of platen movement controlled by a pacing disk, skill and care (or lack of it) in the operation of the testing machine cannot be disregarded as an important source of variability. Until sufficient information to separate the effects of specimen making and testing machine operation is available, mixes should be treated also as separate batches for testing machine operation. Where "between-mix" variation is mentioned below and the number of mixes to obtain a given degree of precision is discussed, it is assumed that each mix is tested as a separate batch, that is, it is the combined variability arising from both specimen preparation and specimen testing which is being considered.

Examination of the data summarized in Table III shows that a low coefficient of variation is usually associated with a low "between-mix" variation. The variance associated with any measurement can be considered as made up of two parts, one due to the "within-mix" variation (S^2) and one due to any additional variation caused by mix-to-mix ("between-mix") variation (S_m^2). In Fig. 4 the coefficient of variation has been plotted against the ratio S_m^2/S^2, and although the data show considerable scatter the general association of low values of S_m^2/S^2 with low values of the C.V. is obvious. From this figure it can be seen that when the C.V. is less than 4 per cent S_m^2/S^2 is usually less than 0.5; when the C.V. rises to 5 per cent S_m^2/S^2 may rise to about 1.5, and when the C.V. rises to 6.5 per cent S_m^2/S^2 may rise to about 3.5. A study of the coefficients of variation and variance ratios shown by the various operators who took part in this investigation, together with the histograms of Fig. 3, suggest that the



First half of Table III shows plasters A (first experiment) D, and F. Second half of Table III shows plasters A (second experiment) B, C, and E.

Fig. 4.—Relationship of coefficient of variation to S_m^2/S^2.

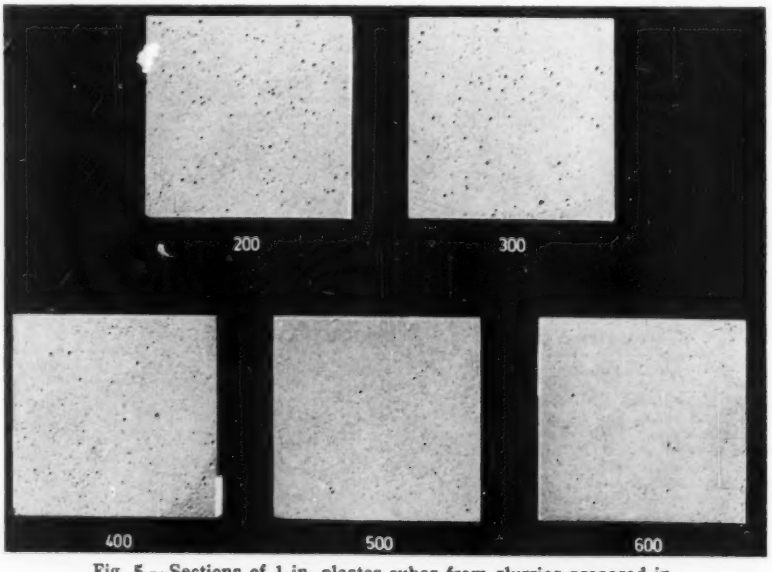


Fig. 5.—Sections of 1-in. plaster cubes from slurries prepared in the Hiraki mixer at different speeds showing de-airing produced at higher speeds. (Numbers below specimens are rpm).

TABLE X.—PRECISION OBTAINABLE WITH 95 PER CENT CERTAINTY FOR FIVE CUBES FROM ONE MIX AT VARIOUS VALUES OF THE COEFFICIENT OF VARIATION.

C.V. = 4 per cent $S_m^2/S^2 = 0.5$	C.V. = 5 per cent $S_m^2/S^2 = 1.5$	C.V. = 6.5 per cent $S_m^2/S^2 = 3.5$	C.V. = 8 per cent $S_m^2/S^2 = 4$	C.V. = 10 per cent $S_m^2/S^2 = 4$
±5.5 per cent	±8 per cent	±11.5 per cent	±14.5 per cent	±18.5 per cent

first of these conditions represents the results likely to be obtained by a very careful and conscientious operator, the second by an average operator, and the third (or worse) by an uninterested operator.

Examination of Table X shows that only with an unusually good operator will five cubes from a single mix provide a result for which the 95 per cent confidence limits lie within ±5 per cent of the "true" or population mean. Under all other conditions a multiplicity of mixes, tested as separate batches, is needed to give a result of this precision. If a result lying within ±10 per cent of the true mean is acceptable then one mix is sufficient under all except the worst conditions.

Further Questions

These results pose further questions which can only be resolved by the committees concerned with standards:

What precision is required in the results of standard tests on which the acceptance or rejection of a consignment may depend? Is ±5 per cent adequate? Can a less precise result (as may well be obtained under present standard test procedures) be tolerated?

What allowance can be made for lack of precision of such test results? For example, a plaster with a true mean value for compressive strength of 1300 psi may, with a test giving a precision of ±5 per cent, return any value between 1365 and 1235 psi. Should a plaster from which the latter value is obtained be rejected if the standard says "not less than 1250 psi?" This value could, of course, equally well be the extreme high value from a plaster with a true mean strength of only 1176 psi.

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The Identification and Quantitative Determination of Natural and Manufactured Fibers

By S. S. PRAEGER

THE TEXTILE INDUSTRY is expanding continually under the impact of new types of manufactured fibers and modifications of existing natural and man-made fibers. Each year several new fibers appear on the textile market. A review of current scientific periodicals reveals the vast amount of research that is being carried on all over the world to formulate new and improved resins for use in synthesizing new fibers or modifying the older types.

The broad scope of the Federal Textile Fiber Products Identification Act necessitates frequent analytical investigations by manufacturers and merchants in this field to ensure that their merchandise is properly labeled. This paper outlines some of the methods used in the analysis of textile fibers. Stress is laid on the use of selective solvents, since this approach has been found to be extremely successful in the course of many years of practical experience in the author's laboratory.

Numerous references are made throughout this paper to fibers having trademark names. Table I contains a list of these names and their owners.

Identification

Microscopic Examination

Microscopic examination of the dry fibers usually does not reveal sufficient characteristics for identification, especially when fiber mixtures are examined. Therefore a staining solution is customarily added to color the fibers and bring out structural details. Herzberg solution, also known as zinc-chlor-iodide solution, is a suitable stain. According to ASTM Methods for Identification of Fibers in Textiles (D 276)[1], it is prepared as follows:

1. Dissolve 20 g of $ZnCl_2$ in 10 ml of distilled water.
2. Dissolve 2.1 g of KI and 0.1 g of iodine in 5 ml of distilled water.
3. Mix 1 and 2; then add a leaf of iodine.

The fiber specimen is spread out on a slide and 1 to 3 drops of Herzberg solution

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[1] 1960 Supplement to Book of ASTM Standards, Part 10, p. 118.

SIEGFRIED S. PRAEGER obtained his Ph.D. in chemistry at the University of Zurich in 1911. After a distinguished career in the European glue and fertilizer industry, as chief chemist for Aktiengesellschaft vorm. H. Scheidemandel-Motard, Berlin, Dr. Praeger came to the USA and established his own glue-manufacturing business until wartime supply restrictions interfered.

For 15 years, prior to his death in the latter part of 1959, he worked as a research chemist in the textile laboratory of the Division of Industrial Hygiene, New York State Department of Labor. One of his principal interests was the qualitative and quantitative analysis of textile fibers. His two earlier papers in this field were published in 1955 and 1957.

TABLE I.—PROPERTIES

Constituents	Staple Cotton	Mercerized Cotton	Viscose Rayon	Acetate	Arnel	Corval	Topel	Nylon	Perlon	Nylenka
	Cellulose		Cellulose, Regenerated	Cellulose Di-acetate	Cellulose Tri-acetate	Cross-linked Cellulose		Polyamide "66"	Polycaprolactam "6"	
Derivation	Plant	Cotton	Purified cellulose					Adipic acid hexamethylene diamine	Epsilon caprolactam	
Denier	...	...	5.5	3	2.5	3	3	3	3	3
Color	Cream	White								
Ultraviolet fluorescence	Purple		Blue violet	Red violet		Purple		Blue violet		
Microscopic	Twisted, not uniform	Slight twist, not uniform	Striated, uniform diameter	Few striations, uniform diameter		Twisted, not uniform		Round		
Zinc-chloro-iodide reagent stain[b]	Violet			Yellow, soluble	Yellow, swelling	Violet		Brownish yellow	Yellow	
Nitrogen	Negative							Positive		
Halogen	Negative									
Sulfur	Negative		Positive							
Burning test	Flammable, burning paper odor, small residue			Melts, acetic acid odor		Flammable, burning paper odor		Amide odor, round hard bead residue		
Moisture, per cent, 1 g, 105 C, 24 hr	4.3	4.9	7.8	4.1	2.3	9.4	9.6	2.3	3.3	3.5
Ash, per cent, 1 g	0.9	0.1	0.5	0.9	0	0	0	0.3	0	0
Solubilities, per cent, 0.5 g referred to dry basis: H_2O boiling, 50 ml, 1 hr	5.0	0.8	0	0	0	0	0	1.0	0	0
5 per cent NaOH, 50 ml, 20 min[b]	6.0	3.4	0	42.0	50.0	0	0	0	0	0
6 *N* HCl, 50 ml, 10 min (**5**)	2.5	0	1.6	1.0	0	0	0	100	100	100
12 *N* HCl, 50 ml, 10 min (**6**)	5.7	8.5	100	100	100	100	100	100	100	100
60 per cent H_2SO_4, 40 ml, 1 hr (**7**)	5.7	8.3	100	100	100	100	100	100	100	100
70 per cent H_2SO_4, 50 ml, 38 C, 15 min[c]	98.4	100	100	100	100	100	100	100	100	100
90 per cent formic acid, 20 ml, 1 hr (**6**)	1.5	0	0	100	100	0	0	100	100	100
100 per cent acetic acid, 25 ml, 118 C, 15 min (**7**)	3.0	1.6	36.5	100	100	0	0	100	100	100
67 per cent, $ZnCl_2$, 50 ml, 45 C, 5 min (**3, 4**)	4.2	1.0	100	100	100	Viscous mass		0	0	0
70 per cent, NH_4SCN, 50 ml, 100 C, 10 min (**8**)	0	0	0	0	0	0	0	0	0	0
70 per cent, KSCN, 50 ml, 100 C, 10 min (**8**)	0	0	0	0	0	0	0	0	0	0
5.25 per cent, NaOCl, 50 ml, 15 min (**6**)	3.7	0	0	0	0	0	0	0	0	0
Acetone, 50 ml, 30 min	0	0	0	100	100	0	0	0	0	0
Acetone on 5 per cent NaOH residue	0	0	0	0	0	0	0	0	0	0
Dioxane, 50 ml, 24 hr	1.5	0	0	100	100	0	0	0	0	0
Chloroform, 50 ml, 10 min (**9**)	0	0	0	0	100	0	0	0	0	0
Dimethylformamide, 50 ml, boil 10 min (**10**)	0	0	0	100	100	0	0	2.0	100	100
Monochlorobenzene, 50 ml, boil 5 min	0	0	0	0	0	0	0	0	0	0
Metacresol, 50 ml, 100 C, 10 min (**6**)	0	0	0	100	100	0	0	100	100	100

[a] Ownership of trademark names: Arnel, Celanese Corporation of America; Corval, Courtaulds (Alabama) Inc.; Topel, Courtaulds (Alabama) Inc.; Perlon, Vereinigte Glanzstoff G.M.B.H.; Nylenka, American Enka Corp.; Dacron, E. I. du Pont de Nemours, Inc.; Vinyon, American Viscose Corp.; Dynel, Union Carbide Chemicals Corp.; Saran, Dow Chemical Co.; Darvan, B. F. Goodrich Chemicals Co.; Orlon, E. I. du Pont de Nemours, Inc.; Acrilan, Chemstrand Corp.; Creslan, American Cyanamid Corp.; Verel, Eastman Chemical Products, Inc.; Zefran, Dow Chemical Co.; Vicara, Virginia Carolina Chemical Corp.

[b] ASTM Methods for Identification of Fibers in Textiles (D 276 – 60 T), 1960 Supplement to Book of ASTM Standards, Part 10, p. 118.

are added. The slide is covered and placed on the microscope stage for examination at 100 × magnification. The following colors are obtained:

cotton	violet
rayon	violet
acetate	yellow
Dacron	slightly yellow
wool	light yellow
nylon	brownish yellow
Acrilan	light brown

Table I lists the staining reactions and characteristic structural details of all fibers studied. Microscopic observations refer to a longitudinal view of the fibers. Examination of cross-sections are of some help but are not usually required for identification. Many manufactured fibers have round cross-sections with few or no distinguishing characteristics.

OF VARIOUS FIBERS.[a]

Dacron	Vinyon	Dynel	Saran	Darvan	Orlon	Acrilan	Creslan	Verel	Zefran	Vicara	Wool	Silk
Polyester	Polyvinyl		Polyvinylidene	Polyvinylidene dinitrile	Polyacrylonitrile		Polyacrylonitrile methyl methacrylate	Modified acrylonitrile	Polyacrylonitrile	Protein formaldehyde	Protein keratine	Protein fibroin
Terephthalic acid ethylene glycol	Vinyl chloride Vinyl acetate	Vinyl chloride Acrylonitrile	Vinyl chloride Vinylidene chloride	Vinylidene dinitrile	Acrylonitrile	Acrylonitrile vinyl acetate	Acrylonitrile			Zein	Animal	
3	...	2	...	3	3	3	3	3	3	...	...	...
		Cream	Slight yellow	White						Cream	White	
	Slight violet	Slight ivory	Purple	Blue white	Blue violet		Blue white	Light purple		Tan white	Blue white	
		Round, twisted, few striations	Round	Round, uniform	Flat, not uniform	Round, few striations	Flat, not uniform		Round, few striations	Round	Scaled	Round, fine, uniform
Slightly yellow	No stain, swells	Slightly orange	Yellow	Slightly yellow		Slightly brown	Slightly yellow, soluble	Slightly yellow			Yellow	
Negative		Positive	Negative	Positive								
	Positive			Negative				Positive	Negative			
Negative											Positive	Negative
Forms bead	Nonflammable, forms beads			Acrid odor			Shrinks, coal-like residue			Burning hair odor		
0.4	0.4	0.6	3.5	1.4	1.0	0.8	1.3	2.4	1.0	6.1	8.8	4.4
0.2	0.1	0.2	0.2	0	0.6	1.0	0.5	0.9	0.9	0.1	1.1	0
0	0	0	0	0	1.5	0	0	0	0	0	0	0
4.6	0	0	0	100	72.7	8.1	18.5	0	35.0	7.5	100	100
0	0	1.5	0	0	0	0	0	0	0	0	0	0
0	0	1.5	0	0	0	0	0	0	2.0	0	0	100
0	0	0	0	0	0	0	0	0	1.5	0	0	100
2.0	1.5	1.4	4.5	0	4.5	7.0	100	0	3.5	0	0	100
1.0	0	1.2	2.3	0	0	6.0	4.7	3.6	3.0	0	0	3.7
2.0	1.0	2.5	2.5	0	2.0	3.0	0	14.5	2.5	0	0.9	0
0	0	0	0	0	100	100	100	0	100	0	0	100
0	0	0	0	0	82.0	100	100	0	100	0	0	3.0
0	0	0	0	0	100	100	100	0	100	0	0	1.5
0	0	1.5	0	0	0	0	0	0	0	48.5	100	100
0	100	100	1.8	0	0	0	0	7.0	0	0	0	0
0	100	100	0	0	0	0	0	0	0	...	...	...
0	100	0	4.5	0	0	0	0	0	0	0	0	0
0	100	0	0	0	0	0	0	0	0	0	0	0
98.5	100	100	100	100	100	100	100	100	100	0	0	0
0	100	3.0	100	0	0	0	0	0	0	0	2.5	0
100	100	Lumps, partly dissolves	Turns brown, partly decomposes	0	0	0	0	Swells, absorbs reagent	0	0	0	0

Solubility

The solubility of fibers in various solutions is a very important factor in making a qualitative examination. A few examples may be given: nylon is soluble in 6 *N* HCl; wool and silk dissolve in 5.25 per cent NaOCl; triacetate and Vinyon are soluble in chloroform; Dynel, acetate, triacetate, and Vinyon dissolve in acetone.

Ultraviolet Fluorescence

Fluorescence in ultraviolet light is characteristic for some fibers in the undyed and unmixed states. For example,

cotton	purple
viscose rayon	bluish violet
acetate	reddish violet
Dynel	light ivory
Vicara	tannish ivory
wool	bluish white

Burning Tests

A small tuft of fibers is held in a small flame. Any odor, melting, or ash is noted. Vegetable fibers produce an odor of burning paper and leave very little ash. Animal fibers and regenerated protein fibers (Vicara) produce an odor of burning hair and leave a black coal-like bead. An odor of acetic acid is given off by acetate fibers, while acrylic fibers produce an acrid odor.

Some synthetic fibers such as Dynel and Saran do not ignite; they melt and leave a bead-like residue. See Table I for data on other fibers.

Qualitative Chemical Tests

Whenever positive identification of a fiber is not obtained by the above tests, a qualitative analysis should be made for the presence of nitrogen, halogen, and sulfur. Using the Lassaigne sodium fusion procedure (**1**),[2] the presence or absence of these elements can be determined in 10 to 15 min by the following method:

Make a small round opening in a 5-in.-square asbestos mat. Place the mat on an iron tripod and insert a small soft glass test tube, held in a metal test tube holder, into the opening. Drop a piece of sodium approximately 5 by 5 by 2 mm into the test tube and heat gently until it melts. Then roll a small tuft of approximately 25 mg of fibers into a small ball, drop it into the test tube and push it carefully to the bottom with a glass rod. Using a Meeker burner heat the bottom of the tube gently for 1 min and then vigorously to a red glow for at least 1 additional min to oxidize the unused portion of sodium. Place a small beaker over the top of the test tube. Place a 50-ml beaker containing 10 ml of distilled water under the glowing test tube and raise to crack the tube by immersion. Decant the aqueous solution through a 9-cm filter to remove glass fragments. Use half the filtrate for the nitrogen test and the remainder for the halogen and sulfur tests.

Nitrogen Test

Reagents:

5 per cent NaOH solution.

Dissolve 1 g of $FeSO_4$ in 100 ml of water and add 0.2 ml of concentrated H_2SO_4.

Dissolve 5 g of $FeCl_3$ in 100 ml of water. Add 1 to 2 drops of concentrated HCl to keep the solution a clear light-brown.

Concentrated HCl.

Keep the ferrous sulfate and ferric chloride solutions protected from light.

Procedure:

To about 5 ml of the filtrate, add 2 ml of 5 per cent NaOH and then 2 ml of $FeSO_4$ solution. Blow air through a glass tube into the liquid. Add 1 drop of concentrated HCl and shake. Repeat until the solution clears. Add 12 drops of $FeCl_3$ solution, mix, and let stand for 10 to 20 min. Formation of a blue precipitate (Prussian blue) indicates the presence of nitrogen.

Halogen Test

Reagents:

Concentrated HNO_3.

2 per cent $AgNO_3$ solution or 0.1 *N* $AgNO_3$ solution.

Procedure:

Acidify 2 ml of the filtrate with a few drops of concentrated HNO_3. Boil this solution gently for a few minutes or until the volume is reduced to one half, to volatilize HCN or H_2S. Filter if cloudy. Add 1 to 2 ml of $AgNO_3$ solution. Formation of a white or yellow precipitate indicates the presence of a halogen.

Sulfur Test

Reagents:

0.5 per cent sodium nitroprusside solution, prepared fresh every 2 weeks.

1 per cent lead acetate solution or lead acetate paper.

Procedure:

Add one drop of the sodium nitroprusside solution to a few drops of filtrate on a white spot plate. Formation of a violet or purple color indicates that the fibers contain sulfur. The color fades quickly. This result can be confirmed by neutralizing 2 ml of the filtrate with acetic acid and then either adding a few drops of lead acetate solution or just dipping lead acetate paper into the solution. A brown or black coloration indicates the presence of sulfur.

Other Qualitative Tests

The presence of polyester fibers containing terephthalate groupings can be confirmed by boiling the fibers in 40 per cent NaOH solution. Polyester fibers decompose and form a milky solution which becomes clear upon dilution with cold water. When the solution is acidified with concentrated HCl, a white crystalline precipitate of terephthalic acid will be formed. This precipitate can be identified, and distinguished from orthophthalic acid, by heating in a test tube; the terephthalic acid sublimes above 300 C without melting, whereas orthophthalic acid melts without subliming.

Another confirmatory test is given by the Ripan reaction (**2**). Terephthalic acid gives a blue precipitate with cupric sulfate and pyridine; orthophthalic acid gives no precipitate.

Quantitative Determination of Fibers by Use of Selective Solvents

When an unknown sample contains only one type of fiber, identification is usually obtained by microscopic examination followed by qualitative tests. However, when the sample contains a mixture of fibers, preliminary identification is supplemented by quantitative methods for determining the percentage composition of the fiber mixture. Procedures based on the use of selective solvents are of great value for this purpose.

In order to develop quantitative procedures, a thorough study of fibers in different solvents was undertaken (**3, 4**). Samples of known fibers obtained from manufacturers and dealers were used as standards. The results are summarized in Table I, which contains a comparison of the properties of the various fibers.

Procedure

To obtain a representative test specimen, the fibers should be cut into short lengths and well mixed. The author has found that the solubility is not significantly affected by cutting the fibers.

Since determinations are made on a dry basis, it is necessary to know the moisture-free content of the original sample. This is obtained by drying a 1.000-g specimen to constant weight at 105 C. Usually a 2-hr drying period is sufficient.

A 0.500-g specimen of fibers is treated with a solvent as outlined in the first column of Table I, then transferred to a fritted glass crucible (Corning C), filtered with suction, and washed. The following precaution should be taken: If a fiber dissolves without decomposition, the residue must be washed repeatedly with the solvent to remove any trace of the dissolved fiber. Completeness of removal can be determined by diluting the washings with distilled water or other liquid that is compatible with the solvent, but which does not dissolve the particular fiber. The dilutions must be clear before washing of the residue is continued with three small portions of cold water followed by three portions of hot (not boiling) water.

For example, acetate is soluble without decomposition in acetone, therefore any residue has to be washed first with acetone. If a fiber is decomposed by the solvent, as wool is by 5.25 per cent NaOCl, the residue should be washed immediately with cold and hot water. Residues should be given three final washings with small portions of ethyl or isopropyl alcohol to remove adhering water, thereby reducing the drying time to 1 hr from a minimum of 2 hr. This procedure also yields a soft, easily removable residue which otherwise would be hard and baked. Whenever a specimen is treated with several selective solvents in the course of an analysis, the same crucible should be used for collecting the different residues.

To illustrate a hypothetical case, assume that microscopic examination of a sample has indicated the presence of a mixture of acetate, nylon, wool, and Orlon acrylic fibers. To dissolve the acetate fibers, treat a 0.500-g specimen with 50 ml of acetone in a beaker by stirring the fibers for 15 min at room temperature, then filter the solution through a weighed fritted glass crucible using suction. Wash the residue twice with 20 ml of acetone to remove all traces of acetate. Rinse with cold and hot water and finally with alcohol. Dry the residue at 105 C for 1 hr, cool in a desiccator, and weigh. To dissolve the nylon, place the residue in a beaker with 50 ml of 6 *N* HCl for 10 min at room temperature. Filter off the acid and wash the residue of wool and Orlon twice with 6 *N* HCl, then with cold water, hot water, and finally with alcohol. Dry, cool, and weigh. To remove the wool, treat the remaining fibers with 50 ml of 5.25 per cent NaOCl for 15 min at room tempera-

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

ture. Wash the Orlon residue with cold, then hot water, and alcohol. The dried residue consists of Orlon acrylic fibers which can be observed by microscopic examination. Make a chemical confirmation by treating the residue with the proportionate amount of 67 per cent $ZnCl_2$ at 45 to 50 C for 5 min, or 70 per cent KSCN at 100 C for 10 min (see Table I). The residue should dissolve completely.

Assuming the moisture content of the specimen to be 2.8 per cent, the 0.500-g specimen has a dry weight of 0.486 g. The fiber composition of the specimen is as follows:

Solvent	Residue, g	Soluble Matter	
		g	per cent
Acetone	0.398	0.088	18.1 acetate
6 *N* HCl	0.294	0.104	21.4 nylon
5.25 per cent NaOCl	0.124	0.170	35.0 wool
67 per cent $ZnCl_2$ or 70 per cent KSCN	none	0.124	25.5 acrylic fibers
Total		0.486	100.0

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Loss of Moisture from Fresh Mortars to Bricks

By J. I. DAVISON

THE STUDY of rain penetration through masonry walls has been an active project in the masonry research program of the Division of Building Research (DBR) of the National Research Council of Canada since the Division was formed in 1947. This is one of a series of papers reporting progress in masonry studies carried out at the DBR Atlantic Regional Station in Halifax, Nova Scotia.

Leakage tests on small brick panels at DBR confirmed observations of previous workers that unbonded areas between brick and mortar commonly form a means for the penetration of rain through brick masonry. Most leaks occurred at the interface between the top of the mortar bed and the bottom of the brick. In bond strength tests on such panels, most fractures occurred with the brick "lifting" from the mortar bed. Many times the leakage path, outlined by staining from

Leakage and bond-strength tests on small brick panels have indicated a weaker bond between a mortar bed and the brick above than between the mortar bed and the brick below. Loss of moisture from fresh mortars to bricks was studied in an effort to explain this difference. Loss of moisture from three mortars having different water retentivity values was determined after timed intervals of contact with bricks having different rates of suction. Moisture loss increased with the suction rate of the brick, except for brick with very high suction rates. The effect of water retentivity of the mortar on moisture loss is also shown. The effect of moisture loss on the plasticity of the mortar is then considered, and the presence of a moisture gradient in the mortar bed is indicated. The pattern of moisture loss to bricks having similar suction values but manufactured with different materials and by different processes is also investigated. Results are discussed in the light of field observations of masonry construction practices.

J. I. DAVISON, an assistant research officer with the Division of Building Research of the National Research Council of Canada, has been engaged since 1958 in a study of the materials used in masonry construction and of the leakage problem in masonry walls at the Atlantic Regional Station in Halifax, where aspects of the problem peculiar to the coastal area are of prime concern.

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impurities in the water, was found on the top of the mortar bed.

Both leakage and strength tests pointed to a weaker bond between the mortar and the brick above than between the mortar and the brick below. Also, inferior bonding occurred more frequently in panels containing bricks with higher initial rates of absorption (IRA).

In a preliminary study at the Atlantic Regional Laboratory, an attempt was made to measure the plasticity or "floating condition" of a mortar bed cast on a brick by placing a second brick on the mortar bed then applying a horizontal force to the brick to displace it on the mortar. An appreciable stiffening of the mortar bed took place in a short time, and attention was thus drawn to the effect of withdrawal of moisture from the mortar. Other investigators had recognized the significance of this loss of water from the mortar bed, but it did not appear that any systematic study of it had ever been made.

Such a study, therefore, was undertaken to provide quantitative evidence of water withdrawal from mortar, and to ascertain the resulting effect on its plasticity.

Water in Mortar

Water is an essential ingredient in a mortar. It serves two prime functions: (1) it is the only liquid, thus contributes to workability—an essential property in placing mortar in a wall; (2), it combines chemically with cementitious materials of the hydraulic type, resulting in the setting or hardening of the mortar.

When a mortar is mixed, enough water is added to provide the degree of plasticity required for workability by the mason. The plasticity or workability of the mortar defines its ability to flow or spread into all the area of the brick face, the bumps and hollows, the cracks and crevices, and thus determines the intimacy of contact between the brick and mortar. It may, therefore, affect both leakage and bond-strength characteristics of the assemblage.

The moisture content of a mortar theoretically starts to decrease by evaporation as soon as the water is added to the mixture. After mixing has been completed and the mortar is cast upon a brick, the rate of moisture loss increases as water is "sucked" into the pores in the surface of the brick. This lowers the plasticity of the mortar bed, which means that its bonding ability will be somewhat less when a brick is placed on the mortar than it was when the mortar was cast upon the brick beneath. This may explain the difference in bonding between mortar and the bricks above and beneath it.

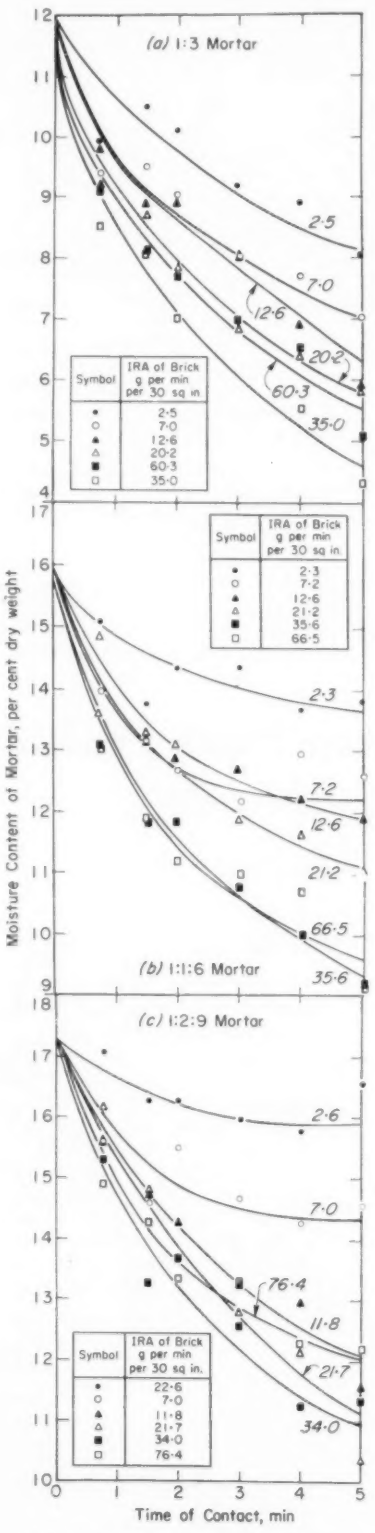

Fig. 1.—Influence of brick suction on moisture loss from mortar.

Moisture Content Losses

In the first phase of this study the moisture content of a $\frac{3}{8}$-in. mortar bed cast upon bricks of known suction was determined at timed intervals from the point of contact. Three mortars were used. The first was composed of masonry cement and sand in proportions by volume of 1:3. The second and third mortars contained portland cement, lime putty, and sand in proportions 1:1:6 and 1:2:9 by volume. Bricks of six different suction rates were used, ranging from 2.5 to 75.0 g per min per 30 sq in.

Mortars were prepared from commercial materials commonly used locally and were designed to have flow values between 110 and 120 per cent. The three mortars had the following water retention values:

Type of Mortar	Water Retention Value, per cent
1:3 masonry-cement	73.4
1:1:6 cement-lime	79.0
1:2:9 cement-lime	91.4

Evaporation loss from mortars was checked before moisture-content determinations were started. The moisture contents of the three mortars were determined at timed intervals after completion of mixing. Results for the 5-min period used in subsequent moisture-content determinations indicated negligible evaporation losses under the conditions of the experiment (temperature 70 F, relative humidity 50 per cent).

Moisture-content values, which were obtained by the oven-dry method, are shown in Fig. 1 in relation to the initial rate of absorption of the brick and the time of contact between mortar and brick.

Discussion of Results

A substantial reduction in the moisture content of all three mortars occurred during the 5-min contact with bricks. Greatest proportion of the total loss took place during the first 2 min of contact. After this, the rate of loss continued at a decreasing rate to the end of the 5-min period. The total moisture loss during the contact period increased with the "suction" of the brick until relatively high suction values were reached. This is shown in Fig. 2, which shows total losses from the three mortars to the various bricks for a 4-min contact period.

The total moisture loss to high-suction bricks for the 4-min period is less than the loss to bricks of lower suction. Anderegg[1] observed a higher moisture loss to bricks of intermediate suction than to those with high rates of suction, and he explained that with

[1]F. O. Anderegg, "The Effect of Brick Absorption Characteristics Upon Mortar Properties," *Proceedings*, Am. Soc. Testing Mats., Vol. 42, pp. 821–36 (1942).

the latter bricks a highly congealed layer of mortar tended to form at the interface with the brick shortly after contact between the two. This layer acts as a barrier which retards the rate of moisture loss.

Figure 2 also illustrates the effect of increasing water retentivity of a mortar on moisture loss. Greatest losses occur from the masonry-cement mortar, which has the lowest retentivity; the smallest losses are from the 1:2:9 cement-lime mortar, which has the highest retentivity.

Effect of Reduced Moisture Content on Plasticity

The three mortars were mixed with a range of water quantities, and the flow and moisture content were determined. Results, shown in Fig. 3, indicate substantial reductions in flow with comparatively small moisture-content reductions. For example, a reduction in flow from 115 to 90 per cent occurs with a loss of 10 per cent of the total moisture content at the upper flow limit for the 1:2:9 cement-lime mortar. The same reduction in flow results from a moisture loss of 9.2 per cent from the 1:1:6 cement-lime mortar and a 7.0 per cent loss from the masonry-cement mortar.

Thus it is concluded that loss of a relatively small percentage of the total moisture content can result in a significant drop in the flow of a mortar, and also in the plasticity of that mortar, assuming that a mortar is less plastic the lower its flow.

Moisture Gradient in the Mortar Bed

Conclusions reached concerning the "bonding life" of the mortar bed after its contact with a brick are based upon the assumption that moisture losses occur equally from all parts of the mortar bed. It is possible, however, that there is a moisture gradient resulting from maximum losses at the mortar surface in contact with the brick, and that the amount of moisture lost decreases as the distance from the interface increases. Visual examination of specimens removed from the mortar beds during moisture content determinations revealed that mortar at or near the contact surface was dry and stiff in appearance in comparison with the wetter and more plastic mortar at the top of the mortar bed.

Anderegg[1] noted the presence of a moisture gradient in mortar beds after short periods of contact between two bricks, but does not mention the condition of the mortar bed prior to the bedding of the second brick.

The possibility was considered of developing a direct measurement of the surface plasticity of the mortar bed, similar to that undertaken in early studies at DBR, but it was discarded in favor of a direct determination of the moisture-content gradient.

The method consisted of determining moisture contents of the top and bottom portions of a mortar bed after short periods of contact with a brick. A ½-in. mortar bed was cast upon a brick of known suction in a mold whose sides were divided at half the height of the mortar bed. After the mortar bed was cast, the upper part of the mold was removed and the top half of the mortar was then taken off by running a metal straightedge along the upper surface of the bottom part of the mold. The bottom half of the mold was then removed and the lower portion of the mortar bed scraped off. Specimens from both layers of the mortar bed could thus be taken almost simultaneously for moisture-content determinations. Two of the mortars previously used, 1:3 masonry-cement and 1:2:9 cement-lime, were investigated during contact with bricks of various suctions, and results are shown in Fig. 4.

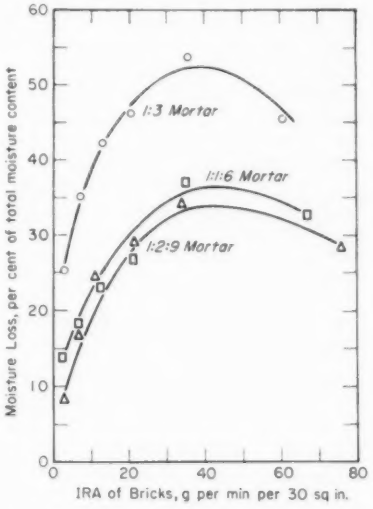

Fig. 2.—Moisture loss versus brick suction (contact time 4 min).

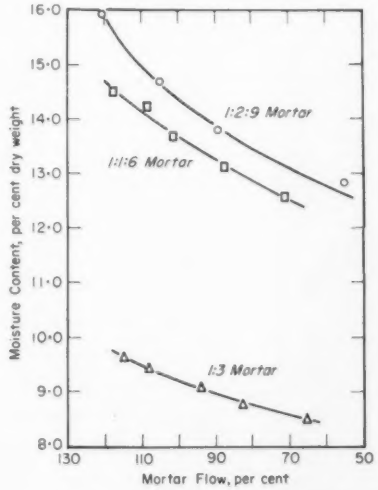

Fig. 3.—Effect of moisture content on flow.

The results clearly establish the presence of a moisture gradient in the mortar bed, for in all cases the moisture content of the top layer is substantially higher than that of the bottom layer.

It is also noted that in four of the combinations studied the moisture content of the top layer did not drop significantly below the original moisture content of the mortar for 2 min, thus indicating that the plasticity of the surface of the mortar may not have been appreciably reduced to that time.

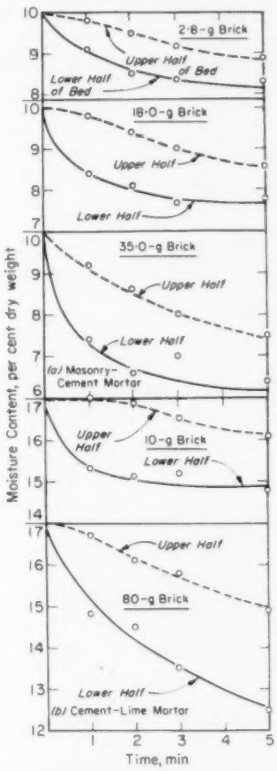

Fig. 4.—Moisture content of upper and lower halves of mortar beds cast on bricks of various suctions.

The exception is the combination of masonry-cement mortar and 35-g[2] brick. The improved result for the 1:2:9 cement-lime mortar and 80-g brick is explained by the higher retentivity of this mortar.

Initial Rate of Absorption as a Measure of Moisture-Content Reduction by the Brick

During the initial phase of this study it was noted that moisture loss from mortar to brick increases as the IRA of the brick increases. Various bricks were used including red, buff, and brown stiff-mud bricks manu-

[2] Initial rate of adsorption of 35 g per min per 30 sq in.

factured by the same company in two different plants as well as red dry-press brick manufactured by a different company. Differences in various clays used and different manufacturing processes could possibly result in differences in the pore structure of the finished product. One brick might have a large number of fine pores while another might contain only a few large pores. In other instances the difference might lie in the shape of the pores. These combinations might result in bricks having identical IRA values but different absorption patterns beyond the 1-min period.

Before suggesting IRA as a yardstick for predicting moisture-content losses, it was thought desirable to investigate the moisture loss from mortars in contact with different bricks having the same IRA.

Moisture-content determinations were made on specimens removed at timed intervals up to 5 min, from mortar beds cast upon bricks. Mortars used were a 1:3 portland cement and sand plus 10 per cent hydrated lime; and a 1:1:6 cement, lime putty, and sand. The cement mortar was chosen for its low water-retention value (40.1 as opposed to 79.0 for the cement-lime mortar).

Seven different bricks were used, with five of the stiff-mud variety manufactured by one company in two different plants, including three buff, one red, and one brown brick. The other two were red dry-press bricks manufactured by different companies. Eight combinations (pairs of different bricks with similar IRA values) were investigated convering an IRA range from 1.1 to 47.3 g. Typical moisture-loss curves are shown in Fig. 5.

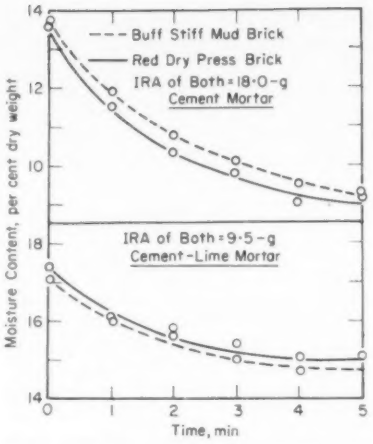

Fig. 5.—Moisture loss from cement and cement-lime mortars to different bricks having similar initial rates of absorption.

Discussion of Results

The moisture-loss curves were all quite similar for mortars in contact with different bricks having similar IRA values. Minor differences which developed in two of the comparisons were inconsistent with each other and are believed to have resulted from differences in IRA values across the area of an individual brick. Results, therefore, indicate similar moisture-loss patterns from mortars to bricks with similar IRA values regardless of differences in manufacture.

Comparison With Field Observations

Field studies have shown that it is not unusual for a bricklayer to lay out a mortar bed 6 to 8 ft in length; with such a long bed it may take 3 to 5 min to bed all the bricks in the mortar. There is a marked difference, however, between the bricklayer's mortar bed and that which has been used in the laboratory, in that the former is not "leveled off" to approach its final thickness, in contrast with the laboratory procedure of reducing the mortar to a $\frac{3}{8}$-in. depth. In the field the mortar bed is thus considerably thicker during the "wait period" and is reduced to its required thickness only when the brick is shoved into place. The effect of a longer "wait period" therefore, may be compensated for by extra thickness of the mortar bed.

Conclusion

Moisture-content determinations on three mortars during a 5-min period of contact with bricks in six IRA ranges have revealed a substantial drop in moisture content during this period.

Moisture-content losses for each mortar increased as the IRA of the bricks increased until relatively high, IRA values were reached, the total moisture loss to very high IRA brick is less than the loss to intermediate IRA brick.

Moisture losses from mortars decreased as the water retentivity of the mortar increased.

Reduction of the original moisture content of the mortar is accompanied by a lowering of the plasticity or "bonding ability" of the mortar, and the loss of moisture from the mortar results in a gradient of moisture content in the mortar.

Loss of moisture from the mortar bed with the resulting reduction in "bonding ability" may explain inferior bonding at the interface between the mortar bed and the brick above it, as compared with the bond between the mortar bed and the brick beneath it.

Johann Bauschinger

(1834–1893)

JOHANN BAUSCHINGER was professor of mechanics and graphical statics, College of Engineering, Munich. He established the first modern public testing laboratory in Germany, and in the process devised a number of testing methods and the apparatus for performing them. His reports, *Mittheilungen in der Hochschule, München*, are well recognized contributions to our knowledge of materials and their properties. The Bauschinger effect, which describes the effect of microstresses on the behavior of metals, bears his name.

This is one of a series of photographs from a collection compiled by Prof. Jasper O. Draffin and displayed in the Arthur N. Talbot Laboratory, University of Illinois.

The Slow Growth and Rapid Propagation of Cracks

Second Report of a Special ASTM Committee[1]

Editor's Note.—The first report appeared in the January and February 1960 issues of the ASTM BULLETIN.

DISCUSSIONS OF THE committee's first report (1)[2] with interested individuals have shown that there is need for some clarification of the practical applications of fracture mechanics concepts. While this is discussed in the earlier report, it appears that more detailed discussion of certain points would be desirable. The main issue centers around the so-called slow crack growth which occurs prior to the onset of rapid propagation, and at lower stresses.

Mechanics of Crack Growth

The purpose of fracture mechanics is to establish useful quantitative relationships between three features of a load-bearing structure containing a crack and to make use of these relationships. These three features are (1) the dimensions of the crack, (2) the nominal elastic stress field in the vicinity of the crack (that is, the stress field, due to the loads acting on the structure, which would exist in the absence of the crack), and (3) such properties of the material as govern the stability of the crack under stress. Knowing the necessary relationships, one can determine the pertinent properties of materials by experiments with comparatively simple specimens and use these to predict the behavior of more complicated structures.

The behavior of the crack, whether it remains at its original size, grows larger gradually, or propagates rapidly, will depend upon the characteristics of the actual elastic stress field which surrounds it and on the material properties. The actual elastic stress field is the result of the modification of the nominal stress field by the presence of the crack. In general, to specify a stress field one must specify the values of each of the six independent scalar components of a second-order, third-degree, symmetric tensor at each point. Fortunately, it has been shown that only two scalar parameters are required to specify the stress field surrounding a crack; the tensor components are given in terms of the coordinates, and the two parameters by a set of equations (2,3). Thus the behavior of the crack depends only on the values of the two parameters which specify the stress field. For purposes of simplicity, and in the absence of contrary experimental data, it is usual to neglect one of the parameters, σ_{oz}, as being of trivial significance. The remaining parameter, the stress field intensity factor, K, is the quantity representing the combined effect of crack dimensions and nominal stress field which influences the behavior of the crack.

If loads are applied to any structure containing a crack, so that tensile stresses act to open the crack, the value of K increases linearly with the value of the nominal tensile stress component normal to the crack. As the value of K increases, some point will be reached at which the crack will start to increase in length. This point will depend upon the material. At first the crack extension process is self-limiting—it will not continue unless the nominal stress continues to increase. This is a consequence of plastic deformation which occurs in the vicinity of the advancing crack front, in effect increasing the resistance to further extension of the crack. In this stage each small increment of stress which causes the crack to extend further also increases the plastic zone size, and hence increases the resistance to crack extension, so that the crack extension per small unit increment of stress is limited. However, the amount of crack extension per unit stress increment increases as the stress increases, and eventually the process ceases to be self-limiting, so that crack extension continues without further increase in stress. This is referred to as the onset of rapid or unstable crack propagation—in other words, fracture. The sequence of events is illustrated schematically in Fig. 1. It is helpful to visualize the two-dimensional case of a straight crack in a wide, thin, flat sheet, carrying a tensile stress normal to a crack, but the description applies quite generally.

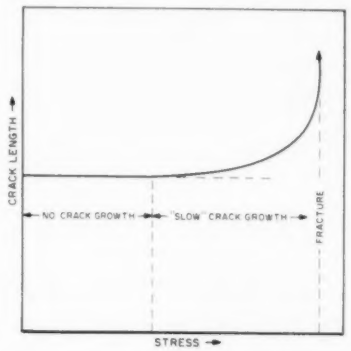

Fig. 1.—Schematic relationship between crack length and stress in a crack-propagation test.

The two singular events in the sequence are the start of slow crack growth and the onset of rapid crack propagation. In principle, either of these, or some arbitrary intermediate point, could be used as the basis of a definition of fracture toughness. In practice, the stress at which slow crack growth starts is usually not well defined, whereas the stress at the onset of rapid crack propagation is sharply defined (for practical purposes it may be taken as the maximum stress reached in a test). The crack length at this point is less sharply defined, since it is increasing rapidly, but it can be measured to a useful degree of accuracy (1). These two quantities determine the value of K at onset of rapid fracture, which is taken as the measure of fracture toughness and designated K_c. It should be noted that the extent of slow crack growth is less the more brittle the material, and in the limit of extreme brittleness the start of slow crack propagation and the onset of rapid fracture tend to coincide. The practical effect of this is that there is less uncertainty in the determination of K_c for a more brittle material.

Practical Application

With this outline of the background, we may now proceed to consider the practical application of K_c measurements. The essential thesis is that for a material having a given value of K_c, rapid crack propagation will ensue whenever the stress-intensity factor, K, of the stress field surrounding a crack in the material reaches the value of K_c. Thus, knowing K_c one can determine the relationship between the fracture

COMMENTS SOLICITED: The ASTM committee writing this report invites the readers to submit comments for consideration. Additional data on this subject would be particularly appreciated. Such correspondence should be addressed to the ASTM Committee on Fracture Testing of High-Strength Metallic Materials, American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

[1] The ASTM Committee on Fracture Testing of High-Strength Metallic Materials.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

stress and the size to which a crack has grown by the time the fracture stress is reached, for any structure that is amenable to the appropriate stress analysis. On the other hand, it is not possible, at present, to relate the fracture stress to the original dimensions of the crack.[3] This is not an inherent limitation of the fracture mechanics approach, but merely a reflection of the present state of development of the subject. Nevertheless, it is a current restriction that needs to be clearly appreciated. It is obvious that research on the slow growth of cracks is of special importance; the factors that may influence the process are: material properties, section size, temperature, environment, and loading history.

The current state of knowledge can be reviewed by considering the behavior of a small surface crack in the wall of a structure for several different sets of circumstances. From the work of Green and Sneddon (**4**), Irwin has derived an equation for the stress-intensity factor around the edge of a flat, semi-elliptical crack which penetrates through not more than half the thickness of a wide, plane plate or sheet and which carries a tensile stress, σ, normal to the crack:

$$[K^2 = 3.77\sigma^2 b/(\phi^2 - 0.212\ \sigma^2/\sigma_{YS}{}^2)] \quad \ldots(1)$$

where σ_{YS} is the tensile yield strength, and ϕ is the elliptic integral function of the ratio of crack depth to half-length, b/a, given by:

$$\phi = \int_0^{\pi/2} \sqrt{1 - \left(\frac{a^2 - b^2}{a^2}\right) \sin^2 \theta}\, d\theta \quad \ldots(2)$$

which is tabulated in standard compilations.

Figure 2 is a plot of ϕ^2 versus b/a.

Brittle Materials

The simplest case to discuss is that in which the environment is inert and the temperature, thickness, and other characteristics of the material are such that it is quite brittle. For all practical purposes the start of slow crack growth will be followed immediately by the onset of rapid fracture, and the critical value of the stress-intensity factor will be the same for both events. The critical value of the stress-intensity factor for this case is given a special designation, K_{Ic}.[4] Here there is no difficulty about the practical application of fracture mechanics. In any situation in which the stress-intensity factor is allowed to reach the value of K_{Ic} for the material, fracture will result. Appropriate stress analysis can be applied to determine the loading conditions at which fracture will occur for any given initial crack dimensions in any structure of interest.

It should not be thought that this case is of mere academic interest; experimental rocket motor chambers have been constructed of materials that are sufficiently brittle to behave in this way.

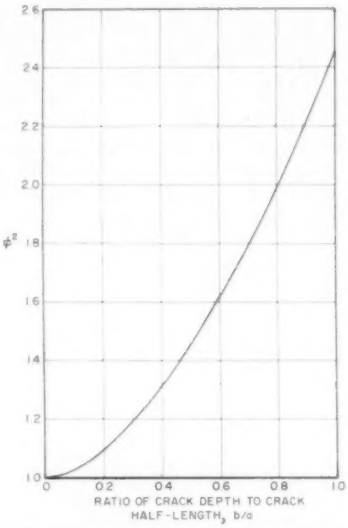

Fig. 2.—Plot of the square of the elliptical integral function of b/a given by Eq 2.

In fact, present indications, based on a large amount of data, suggest that it may not be possible to find a steel having a yield strength greater than 240,000 psi which is not this brittle. As far as current production steels are concerned, the limit is more like 220,000 psi. Critical crack dimensions for steels with greater yield strengths are of the order of hundredths of an inch, or less, when the nominal stress normal to the crack is equal to the yield strength.

The data shown in Fig. 3 illustrate the validity of Eq 1 and refer to a sheet steel heat treated to a brittle condition in which the yield strength was about 210,000 psi (**5**). Strip specimens which were 1, 2, or 3 in. wide and $\frac{1}{16}$ in. thick were provided with roughly semi-elliptical surface cracks of various sizes and then tested in tension. Photographs of several fractures showing the cracks are shown in Fig. 4. The K_{Ic} values calculated from Eq 1, using the initial crack dimensions and the breaking loads, are plotted versus a measure of mean crack size. The values are substantially constant over a considerable range of crack size, within the experimental scatter. The slight tendency for K_{Ic} to decrease with increasing crack size is attributable, at least in part, to the fact that the depths of some of the larger cracks were somewhat greater than half the thickness. Equation 1 is not considered to apply to such deep cracks. The ratio of crack depth to

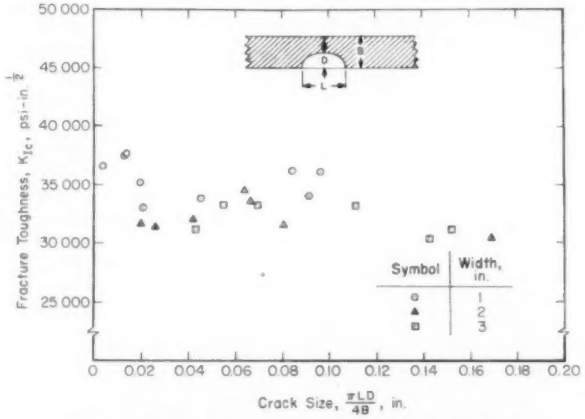

Fig. 3.—Data for a high-strength sheet steel illustrating applicability of Eq 1.

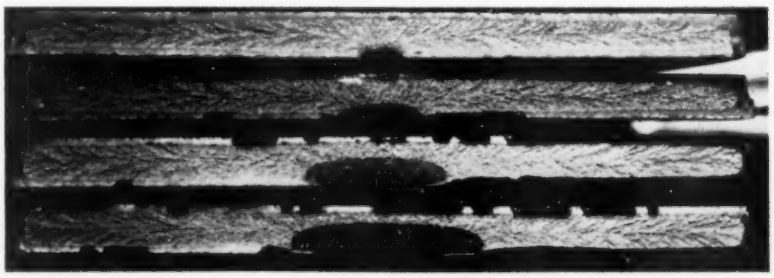

Fig. 4.—Photograph of fractures of specimens used to obtain the data of Fig. 3, showing initial surface cracks.

[3] The increase in crack size prior to onset of rapid crack propagation may be negligible or may be as much as a factor of two or more, depending upon the relative size of the associated zone of plastic strain.

[4] For a given material K_c varies with thickness, and K_{Ic} is the minimum value toward which K_c tends as the thickness increases indefinitely. It is sometimes referred to as the "plane-strain fracture toughness." See reference (**1**) and also Fig. 5 of this report.

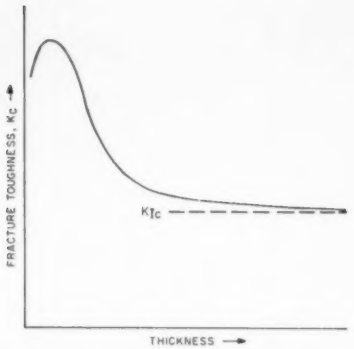

Fig. 5.—General form of relationship between fracture toughness and thickness of a sheet or plate material.

crack length ranged from 0.12 to 0.55. There was no consistent variation of K_{Ic} with this ratio.

If a test is conducted to determine the fracture toughness of a sheet material, using a sharply notched or slotted specimen in the manner described in reference (1), the value of K_c that is measured will depend on the thickness, all other factors being constant. The general form of the thickness dependence is shown in Fig. 5, which is derived from Fig. 5 of reference (1). The value of K_{Ic}, the maximum value of K_c, and the thickness at which K_c has its maximum value, will all depend upon the material, and on the temperature for a given material, but the general shape of the curve will be the same. Evidently, for sufficiently thick materials the value of K_c will approach closely that of K_{Ic}, but for thinner materials some independent method is needed if K_{Ic} is to be determined.

It must also be appreciated that the material may be anisotropic with respect to fracture toughness. In fact, it is likely that this will be the case for sheet materials because of the strongly directional grain flow induced by the rolling process. Referring to Fig. 6, we can distinguish six principal systems of crack propagation by pairs of letters, where the first letter is that representing the normal to the plane of the crack, and the second letter represents the direction of propagation. In a fracture toughness test of a longitudinal specimen from the sheet, the crack propagation system (for the transverse mode of fracturing) is *RW*. For a transverse specimen it is *WR*. For a surface crack it may be *RT* or *WT*. Fracture toughness will probably be lowest for the systems *TW* and *TR*, because of the nature of the grain flow or fibering. Fortunately these are not cases of practical importance, except that splitting on these systems may accompany crack propagation on the other systems in materials which are strongly "layered." This has been observed in steels containing elongated ferrite grains dispersed in austenitic matrices, and actually increases the effective fracture toughness for the *RW* and *WR* systems (6).

Methods of determining K_{Ic} include tests of round notched bars in tension and notched beams in bending. They will not be discussed further here except to note that the specimens are obtained from material that is heavier in section than the sheet, and, therefore, which is not exactly representative of the sheet in respect to metallurgical processing.

Tougher Materials

We may now consider the second case, in which the environment is again inert, but the material is relatively tough in the thickness and at the temperature considered. For present purposes the criterion of relative toughness is that the fracture of the specimen in the usual type of K_c test should be predominantly shear, with little, if any, central transverse band. As in the brittle material, slow crack extension will start when the stress intensity reaches the value of K_{Ic}, but continued crack extension now proceeds against increasing resistance, and therefore requires continued increase in the applied stress. Provided that K_c for the thickness in question is sufficiently greater than K_{Ic}, the eventual unstable fracturing will be controlled

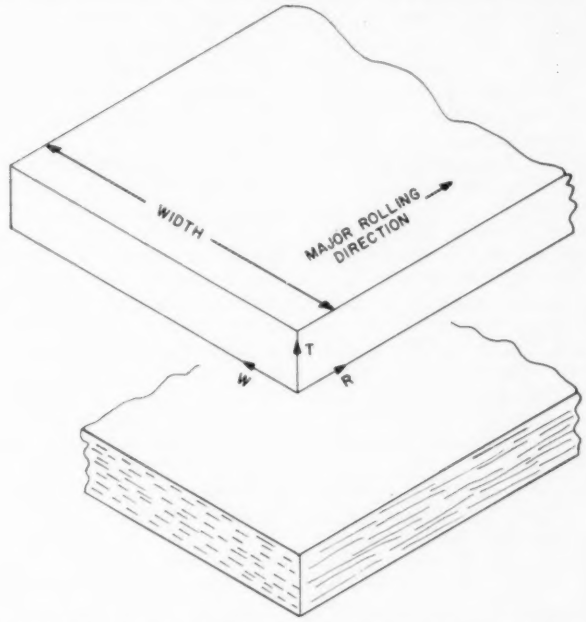

Fig. 6.—Identification of directions in an anisotropic sheet or plate.

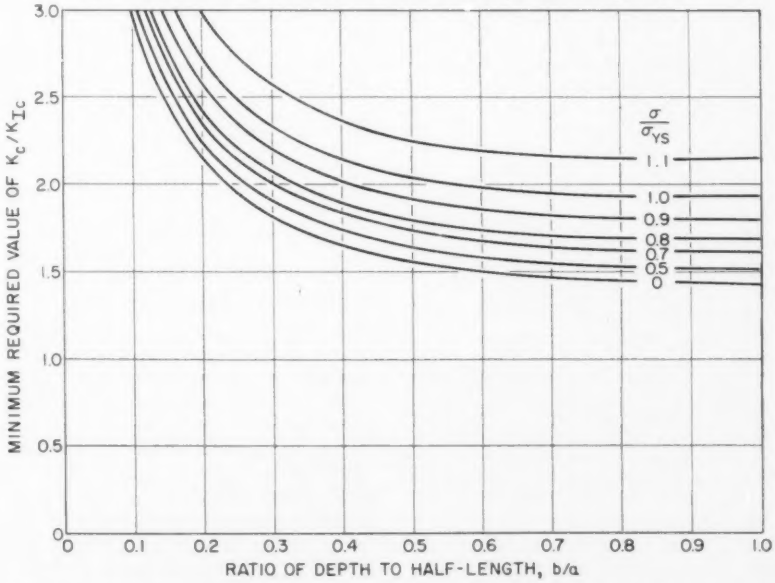

Fig. 7.—Plot of minimum required value of the ratio K_c/K_{Ic} for the fracture stress to exceed the stress for the start of slow crack growth. Basis given in the Appendix.

by the K_c value. The complete sequence of slow crack growth through the thickness of the specimen with increasing stress is too complicated for analysis. However, it is possible to make some reasonable inferences about the eventual onset of unstable fracturing, and a detailed discussion of this question has been given by Irwin (**7**).

The conclusion reached by Irwin is, in effect, that if the quantity $K_c^2/\pi\sigma_{YS}^2$ exceeds twice the thickness of the wall, a small surface crack is unlikely to develop to the stage of unstable fracturing under stresses which do not exceed the yield strength. This quantity is the critical crack length at the yield strength for a through-the-thickness crack, so that the criterion suggested is that the critical crack length for the material should exceed twice the wall thickness. In reference (**1**) this is stated in a different, but equivalent, manner, that is, in terms of the quantity β_c, which is defined as $K_c^2/B\sigma_{YS}^2$, where B is the wall thickness. In these terms, β_c should exceed 2π.

Irwin's criterion does not involve K_{Ic}. A different criterion follows from Eq 1, that unstable fracturing will be governed by K_{Ic}, and independent of the value of K_c, unless the ratio K_c/K_{Ic} exceeds a value which is a function of b/a and of σ/σ_{YS}. This minimum required value of K_c/K_{Ic} is plotted in Fig. 7 as a function of b/a for several values of the stress ratio. The derivation is given in the Appendix.

From this plot it can be determined whether a fracture mechanics analysis, using the initial crack dimensions and the value of K_{Ic}, should be applied. For example, if the ratio of the allowable stress to the yield stress is to be 0.9, then the K_c value will not affect the fracture stress if the ratio of K_c/K_{Ic} is less than about 1.8, and thus the use of the K_{Ic} value is indicated. If the value of the ratio exceeds 1.8, then the Irwin criterion should be applied.

Environmental Effects

Up to this point it has been assumed that the environment for crack propagation is inert and has no effect on the process. However, certain environments have a very pronounced effect, which can be thought of as promoting slow crack extension at levels of the stress intensity, K, less than the value of K_{Ic} which would be determined in the absence of the environment. Processes such as stress-corrosion cracking or hydrogen-embrittlement cracking are examples, but for present purposes the mechanism need not be considered.

In the case of the more brittle materials, a crack will grow gradually under the influence of the environment until the level of K reaches the value of K_{Ic}, when unstable fracturing will occur. For the tougher materials, the effect of the environment will be quite similar except that fracture will not occur until K exceeds the effective value of K_c at some stage of crack extension beyond that at which $K = K_{Ic}$. The important point is that, regardless of the toughness of the material, once the stress intensity reaches a value at which environmentally promoted slow crack growth can start, the process will almost certainly continue until fracture occurs, unless the stress is reduced. The environmentally promoted slow crack growth stage may take only seconds, or it may take much longer, depending upon the material, the environment, and the stress level.

It would be possible to express the effect of a given environment on a given material in terms of the lowest level of the stress intensity, K, at which environmentally promoted crack propagation would proceed. Steigerwald has conducted some experiments which confirm the expectation that the critical stress intensity levels can be very low (**8**). Again, as expected, the environmental susceptibility of steels for high-strength rocket-motor casings increases with increasing strength level. In other words, with increasing yield strength the materials tend to become both less tough and more sensitive to environment. The major environmental factor thus far isolated in this case is simply moisture. Incidentally, examples of delayed failures of high-strength steel pressure vessels in the field have been encountered in which the fracture origins were clearly developed by so-called stress-corrosion cracking in the presence of moisture during storage of the vessels under internal pressure.

To attempt to allow for the presence of a detrimental environmental factor by restricting the stress intensity level to less than the critical value in the presence of the environment would be both uncertain and prohibitively restrictive on allowable stress levels. The only really effective way of dealing with the environment problem is to ensure that all detrimental environmental factors are excluded. This can be stated in another way by saying that the material selected must be unaffected by any of the constituents of the fluid that is to be contained in it. If protective coatings are used there must be full assurance of coating integrity.

Thus, while environment is of the greatest importance, it is not normally a factor to be considered in fracture mechanics calculations, but rather, an independent factor in the selection of materials. On the other hand, in the investigation of service failures the possibility of environmental contribution to the failure must not be neglected.

Loading History

Up to this point the implicit assumption has been made that we are concerned with the first application of loads to a structure that has previously not been loaded. Additional complications are introduced if more than one cycle of loading and unloading is applied. At the extreme, of course, the problem becomes one of the familiar types of fatigue failure after a large number of cycles. However, there is also the less familiar possibility of so-called low-cycle fatigue involving only a small number of cycles, perhaps only two. The cycles are not necessarily regular or similar, they may involve periods of steady load. Efforts are currently being made to bring both many-cycle fatigue and low-cycle fatigue within the province of fracture mechanics, and the results so far are quite encouraging. The problem is complex, and more work is needed. A discussion of fatigue in terms of fracture mechanics has been given recently by Paris, Gomez, and Anderson (**9**)

There is no doubt that cycles of loading and unloading have a significant effect on flaws which exist in a structure, and on the material in the immediate vicinity of the flaws. The dimensions and acuity of the flaws may be modified, residual stress systems may be established, strain hardening and strain aging may occur. Without going into detail of submicrostructural processes, the net effect is that the flaws become more damaging and the structure becomes weaker. There are possible exceptional cases, such as crack blunting by stressing at somewhat elevated temperatures prior to loading at a lower temperature (**10**), but these need not concern us here.

One approach to dealing with the over-all effect in terms of fracture mechanics is that of Carpenter (**11**). Essentially, he proposes to determine a subcritical stress-intensity factor value, K_{Sc}, lower than K_c, for propagation of cracks subject to repeated loading. If the stress-intensity factor exceeds the subcritical value, the crack will extend within a fairly small number of cycles and eventually reach critical size. If the stress-intensity factor is lower than the subcritical value, the crack should remain at its original size for the expected number of cycles. It is not known what the relationship is between Carpenter's subcritical stress-intensity factor and K_{Ic}. The experimental data are limited to a very narrow range of strength levels of steels, and to specimens with gross initial cracks, so that it is too soon to discuss the prospects for this approach. Similar work by Corten (**12**) has led to an ingenious, practical suggestion regarding the hydrostatic proof pressure testing of rocket-motor chambers. Indiscriminate repetition of

proof testing is, of course, undesirable. On the basis of his work, Corten suggests that one, and only one proof test, at a pressure 10 per cent higher than maximum expected service pressure, is the best compromise. The results of both Carpenter and Corten show that the stress intensity at which crack extension will occur under repeated loading and unloading may be much lower than K_c. They also show that complete unloading is more damaging than partial unloading between load peaks.

A few results obtained by Beachem (**5**) with specimens containing small surface cracks indicate that the fracture strength of the specimen is reduced with each successive cycle of loading and unloading, even though no appreciable crack growth is evident. This suggests that residual stresses and modification of material properties by local strain are important factors, as might be expected. Beyond this, although considerable work is going on at several centers, there is little information now available on the influence of loading history. The topic is important for obvious reasons. For instance, sudden failures during storage under nominally constant loads have occurred after periods of months. In such cases environmental effects are immediately suspected, but it is possible for such failures to occur in inert environments. Small fluctuations in temperature could bring about fluctuations in stresses in certain locations which would be sufficient to cause gradual (although incrementally discontinuous) extension of cracks.

Conclusion

The necessary fracture mechanics basis is available for extensive, quantitative application to practical fracture problems. There are, however, certain gaps in our knowledge which limit the scope of the applications at the present time. Furthermore, limitations on our ability to discover and measure flaws by nondestructive testing methods imposes a further restriction. This means that allowance must be made for uncertainties about the circumstances of service of a structure.

It is necessary to select a material that is inert to its environment. This being done, fracture will be governed by the value of the so-called plane strain fracture toughness, K_{Ic}, if the value of this exceeds some fraction of the value of the fracture toughness for the section thickness in question, K_c, as shown in Fig. 7. In this case the critical crack dimensions for onset of rapid fracture will be the same as for slow crack extension, and critical crack dimensions for a single loading can be calculated for the assumed loads from the value of K_{Ic}. Calculation procedures are given in the literature, for instance, Eq 1 of this report. The determination of K_{Ic} for the material may present something of a problem, since anisotropy and metallurgical processing differences cannot be neglected. It is expected that this will be discussed at greater length in a subsequent report by the committee.

If K_c for the section thickness in question sufficiently exceeds K_{Ic}, according to Fig. 7, the critical crack dimensions for onset of rapid fracture may be substantially greater than those for slow crack extension. In this case a small fracture origin may start to grow during loading but may reach a stable size at maximum load and not extend further, unless either the load is further increased or fluctuated. Precise analysis of this case is beyond present knowledge, but a useful criterion suggested by Irwin (**2**) can be applied. This is that a small fracture origin is unlikely to develop into a complete fracture if the critical crack length at the yield strength of the material is greater than twice the section thickness. The critical crack length is calculated from the values of K_c and of the yield strength. K_c is determined by tests as described in reference (**1**).

Using one or the other of these two cases, fracture mechanics can be applied to most practical problems if the question of repeated or varying loading can be neglected. If this question cannot be neglected the situation is much less satisfactory, and the application of fracture mechanics measurements in such cases must await further developments which are currently being pursued. However, there is considerable evidence that fracture toughness values are of major importance in these cases also and can at least be used to place materials in order of merit, pending the development of more precise procedures.

APPENDIX

Basis of Minimum Required Value of K_c/K_{Ic} (Fig. 7)

THE VALUE of K_c for a through-the-thickness crack of length $2a_1$ at the onset of rapid crack propagation is given in reference (1):

$$K_c^2 = \pi\sigma_1^2 a_1/(1 - 0.5\ \sigma_1^2/\sigma_{Y_s}^2) \quad \ldots\ldots(3),$$

where σ_1 is the nominal normal stress at onset of rapid crack propagation.

From Eq 1 of the body of this report, the value of K_{Ic} for a semi-elliptical surface crack of initial depth b_0 and length $2a_0$ is:

$$K_{Ic}^2 = 3.77\ \sigma_0^2\ b_0/(\phi^2 - 0.212\ \sigma_0^2/\sigma_{Y_s}^2) \quad \ldots(4)$$

where σ_0 is the nominal normal stress at the start of slow crack growth.

Now, if the through-the-thickness crack has developed from the surface crack by a process of slow crack extension, a_1 cannot be less than a_0, and σ_1 cannot be less than σ_0, hence

$$K_c^2 > \pi\sigma_0^2 a_0/(1 - 0.5\ \sigma_0^2/\sigma_{Y_s}^2) \quad \ldots\ldots(5)$$

and, dividing Eq 5 by Eq 4 and taking the square root:

$$\frac{K_c}{K_{Ic}} > \sqrt{\frac{(\phi^2 - 0.212\ \sigma_0^2/\sigma_{Y_s}^2)\ a_0}{(1.2 - 0.6\ \sigma_0^2/\sigma_{Y_s}^2)\ b_0}}$$

The right-hand side of this inequality is the function that is plotted in Fig. 7. Evidently, for values of K_c/K_{Ic} less than these values, the value of K_c will not affect the fracture stress and the conditions for fracture are controlled by the value of K_{Ic}.

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(6) J. E. Srawley and C. D. Beachem, "Crack Propagation Tests of Some High-Strength Sheet Materials," *Report 5263*, U. S. Naval Research Laboratory, Jan., 1959.

(7) G. R. Irwin, "Plastic Zone Near a Crack and Fracture Toughness," *Proceedings*, Seventh Sagamore Ordnance Materials Research Conference 1960, to be published.

(8) E. A. Steigerwald, "Delayed Failures of High-Strength Steel in Liquid Environments," to be published by Am. Soc. Testing Mats.

(9) P. C. Paris, M. P. Gomez, and W. E Anderson, "A Rational Analytical Theory of Fatigue," to be published.

(10) J. E. Srawley and C. D. Beachem, "Crack Propagation Tests of High-Strength Sheet Materials, Part IV—The Effect of Warm Pre-Straining," *Report 5460*, U. S. Naval Research Laboratory, April, 1960.

(11) S. T. Carpenter, "Low Cycle Fatigue and Fracture Strength of High-Strength Steels," *Problem 62R19-05, Technical Memorandum 123*, U. S. Naval Research Laboratory, May, 1960.

(12) H. T. Corten, "Slow Crack Extension in High-Strength Steels," *Proceedings*, Seventh Sagamore Ordnance Materials Research Conference, 1960, to be published.

Making the Electron Behave

More than 300 register to hear 35 papers[1] at three-day symposium

THE TINY electron is very big these days. Vast human effort is being directed toward the development of ingenious materials and cunning devices for controlling the behavior of this particle-wave. At a three-day symposium in Philadelphia, April 5–7, sponsored by Committee F-1 on Materials for Electron Tubes and Semiconductor Devices, more than 300 engineers and scientists were brought up to date on the latest techniques for making the electron behave. The main problems under attack were how to control and analyze material contaminants, how to achieve the fantastic cleanliness needed in some devices, and how to determine the effects of contaminants and cleaning processes on device performance.

Eliminate People?

If it were not for people, it would be relatively easy to provide quite clean manufacturing facilities for electron device components. Since it is not yet feasible to eliminate people altogether in this kind of manufacturing, it is necessary to work out methods for keeping the work areas as clean as possible. Frank Van Luik told the symposium how the General Electric Co. accomplishes this. Because of the critical nature of many of the devices being assembled, extreme cleanliness is necessary, not only of the air in the work areas but also of the materials being assembled. Mr. Van Luik has been able to measure concentration levels of particles from 50 μ in diameter down to as low as 0.001 μ. The method used for the very small particles involves a cloud-chamber type device called a condensation nuclei detector. This ingenious device introduces the particle into a supersaturated atmosphere so that, for example, a particle less than 0.1 μ in diameter will collect condensed moisture and grow to as large as 10 μ. Then it can easily be counted, using a photoelectric device.

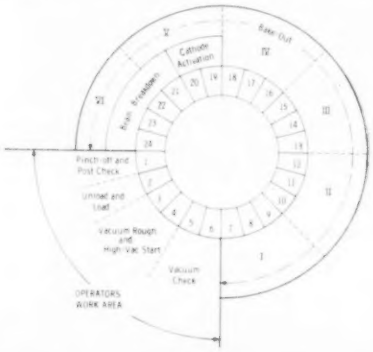
[1] These papers will be published by the Society as Special Technical Publication 300, "Symposium on Materials and Election Device Processing." It is expected that STP 300 will be available early next fall.

What's a Little Dirt Made of?

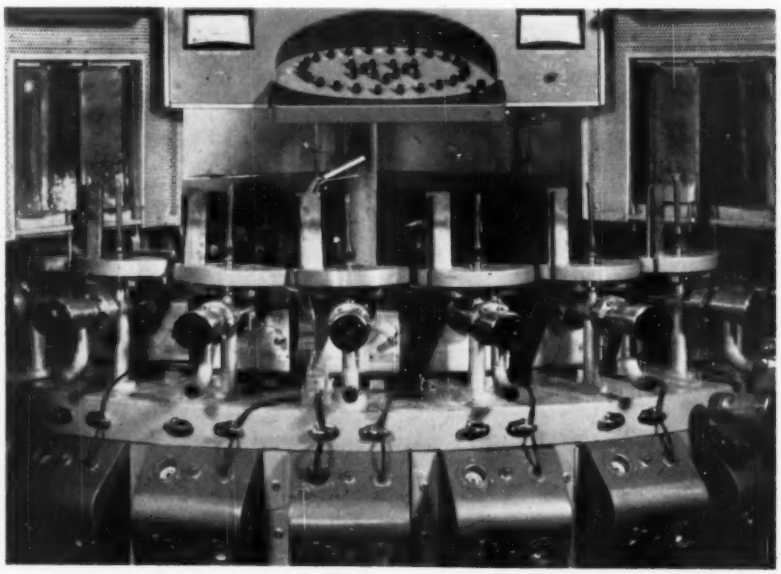
The composition of the particles found in atmospheres of clean rooms is interesting. Of course, among the larger particles one finds hair, textile fibers, bits of skin; and, as the size goes down, such things as metallic oxides, silicon, and metal particles appear. Composition in the submicron range is complex. Certain gases such as, say, sulfur dioxide will be passed by a filter and yet can be converted into particles through photochemical reactions in the work area. Such particles may appear in extremely high concentration levels of, say, 150,000 particles per cu cm of about 0.001 μ diam. Some such particles, while appearing to be too small to be of much consequence, are acidic in nature and may be quite serious for this reason.

One Microgram per Square Centimeter

In some critical manufacturing operations, one is also concerned with cleaning the surfaces of the materials being handled and of determining just how clean the surfaces are. A fundamental property of surfaces, the ability to develop an electrical potential when in contact with an electrolyte, is being used by several companies to detect minute amounts of surface contamination on



Semiautomatic vacuum tube exhaust machine—(below) operator's view, *(right)* schematic plan view. Illustrations taken from "A 24-Position Semiautomatic Vacuum Tube Exhaust Machine," by L. T. Quaglia and G. F. Reyling, Varian Associates.



metals. D. G. Schimmel of Sylvania Electric Products told the symposium how he measures the potential developed, using an extremely weak electrolyte (0.0001 molar) together with a calomel electrode and a sensitive bridge. Both polarity and potential are measured. It is believed that the potential developed is proportional to the amount of contamination on the surfaces, and Mr. Schimmel estimates that it is possible to detect less than 1 μg of inorganic contaminant per square centimeter of surface area by this means.

People Eliminated

The possibilities of automation have also been looked into, and in some cases processes have been rather highly automated. These automated processes are carried out "untouched by human hands," so that contamination introduced by people in the work areas is not a problem. Among the automated devices described was a 24-position semiautomatic vacuum tube exhaust machine described by Larry Quaglia of Varian Associates (see cut). C. O. Thomas told the symposium of the Bell Laboratories' findings in connection with automation of chemical processing to eliminate contaminants from electron tube components.

Some Dowsers, No Drowsers at Dinner Meeting

In his dinner address on Thursday evening, April 6, John Campbell needled his audience to a pitch of buzzing controversy with a swashbuckling attack on conservatism in science and a resounding defense of crackpots. Mr. Campbell, who studied physics at M.I.T. and received his B.S. from Duke University, is the long-time editor of *Analog*, formerly *Astounding Science Fiction*.

The orthodoxist in science, said Mr. Campbell, is a sincere, dedicated, but intransigent individual whose emotional investment in the *status quo* is a devastating block to human progress. Too often, his scientific curiosity is overcome by fear—fear of having the painfully acquired solid ground of doctrine swept from under him, fear of losing his bearings in a topsy-turvy world, fear of the scorn of his peers should he espouse a preposterous idea.

It was because of this fear, said Mr. Campbell, that the orthodoxists refused to look through Galileo's telescope. This same fear is in operation today, he claimed, and because of it we may never know how many scientific breakthroughs are being stifled He named some candidates: Norman Dean's levitation machine; a black box that traps cosmic energy; the mysterious force that guides the hands of the dowser. Science, said Mr. Campbell, may never know whether such things are the work of crackpots or the workings of new

J. CAMPBELL

natural law, because science refuses to look at them.

It may be that Mr. Campbell's tongue was making furtive passes at his cheek during at least part of the evening, but at the end of his talk, after very enthusiastic applause, mixed with a few half-embarrassed smiles, his listeners launched into hot debate. Some took impassioned issue with the speaker, but there were also a number of dowsers in the assembly. After some 20 min of discussion, presiding officer H. W. Stuart felt constrained to call a halt for the sake of those with trains to catch. But very few left the room—the discussion simply continued on a more informal

H. W. STUART

basis for more than another hour before the aroused group had had its fill.

This most enjoyable and stimulating dinner meeting was sponsored by the Philadelphia District Council, whose chairman, H. W. Stuart, presided.

64th Annual Meeting

Atlantic City, N. J., June 25–30

Marburg and Gillett Lectures

Abstracts of the Marburg and Gillett lectures, to be presented on Monday and Tuesday, June 26 and 27, appear on page 396.

Provisional Program Changes

The revised provisional program summary appears on page 397. Full details were given in the April issue of *MR&S*. Since the appearance of the April issue, a paper by Olive Engel, National Bureau of Standards, on "Liquid Drop Collisions" has been added to the Symposium on Erosion and Cavitation (33rd Session). The paper by Messrs. J. E. Srawley and C. D. Beachem on "Fracture of High-Strength Sheet Steel Specimens Containing Small Cracks" will be presented at the Ninth Session; it is listed in the April issue for presentation by title only in the 13th Session. The starting time for the Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service to be held Tuesday morning and afternoon, June 27, and Wednesday morning, June 28, will be 9 a.m. and 2 p.m. rather than 9:30 a.m. and 2:30 p.m.

A panel discussion on precision and accuracy and interlaboratory techniques will be presented Monday morning at 9:30 a.m.

A paper by Joseph Marin, The Pennsylvania State University, on "Creep of Structural Joints from Simple Tensile Creep," has been added to 17th Session (Session on High Temperature). The title of the Symposium on Effects of Minor Constituents on the Properties of Pure Materials should read "Symposium on Major Effects of Minor Constituents on the Properties of Materials."

Several committee reports will be presented at sessions different from those shown in the April issue of *MR&S*. These shifts have been made in the program summary on page 397 and are also listed below:

Committee Report	Shifted From Session	Shifted To Session
A-2	28	4
A-5	35	28
A-6	4	35
A-10	15	28
C-8	(add)	23
C-14	(add)	23
C-17	15	35
D-16	40	35
D-24	(add)	15
E-10	32	35
E-11	4	15
Jt. Comm. Eff. Temp.	(add)	35
Jt. Comm. Leather	(add)	41

MARBURG LECTURE

The Nucleation and Growth of Ice Crystals

BRUCE CHALMERS

BRUCE CHALMERS, Gordon McKay Professor of Metallurgy, Harvard University, will present the Edgar Marburg Lecture on Monday afternoon, June 26. In this annual lecture, a memorial to the first secretary of ASTM, leaders in their respective fields describe outstanding developments in our knowledge of engineering materials.

Dr. Chalmers will discuss the theory of static nucleation and the existence of dynamic nucleation processes. The process of crystal growth from the melt will be examined in terms of the structure of the solid-liquid interface and thermal and chemical conditions. Some experiments on the effect of the temperature and the composition of aqueous solutions on the growth of ice crystals will be described, and the differences between growth within a liquid and growth on the surface of a solid will be accounted for. The phenomenon of dendritic melting will also be discussed. The subject of this lecture has direct implications on the freezing of water in soils, on the manufacture of semiconductors, on zone melting processes, and a host of other applications in the electronics industry and in metallurgy.

Dr. Chalmers is a native of London, England. He received his B.Sc. and Ph.D. degrees in physics at the University of London in 1929 and 1931, respectively. He was awarded the D.Sc. degree by the University of London in 1941.

He lectured in physics and mathematics at Sir John Cass Inst., University or London, from 1932 to 1938. He was physicist at the Tin Research Inst. from 1938 to 1942. In 1942 he became head of the Metallurgy Dept., Royal Aircraft Establishment, Farnboro, and in 1946 became head, Metallurgy Dept., Atomic Energy Research Establishment, Harwell. From 1948 to 1953 he was professor of physical metallurgy, University of Toronto. In 1953 he assumed his present position as Gordon McKay Professor of Metallurgy, Harvard University.

Dr. Chalmers is the author of *Physical Examination of Metals, Structure and Properties of Metals and Alloys,* and *Physical Metallurgy.* In addition he is editor of *Acta Metallurgica* and *Progress in Metal Physics.*

GILLETT LECTURE

"Specifications?!"

A. B. KINZEL

AUGUSTUS B. KINZEL, vice-president, research, Union Carbide Corp., will present the Gillett Memorial Lecture on Tuesday afternoon, June 27. This lecture, jointly sponsored by ASTM and the Battelle Memorial Inst., commemorates Horace W. Gillett, one of America's leading metallurgists and the first director of Battelle.

The title of the lecture refers to the why, how, and finality of specifications. It will include a brief discussion of the nature, history, purpose, and use of specifications. Topics to be explored include: the structure and content of specifications in relation to their objectives; the need for flexibility and judgment as a substitute for ignorance; and the relation of tests and testing to specifications, together with the effect of the nature of the test on the nature of the specification.

The possibilities of specifying in such a way as to make it easier to consider the use of materials beyond their elastic limit will be set forth. The role of engineering experience in specifications and approaches to the true technical worth of a material will be examined. Finally, as part of the story of specifications and engineering, the need for engineering research, and its place in today's picture are stressed, with the thought that specifications may be provided that do have real meaning and finality with respect to specific applications.

Dr. Kinzel received his B.A. *cum laude* in mathematics from Columbia University in 1919, his B.S. in engineering from Massachusetts Institute of Technology in 1921, and doctorates in metallurgical engineering and science from the University of Nancy in France. He was awarded the honorary degrees of doctor of engineering from New York University in 1955 and doctor of science from Clarkson College of Technology in 1957.

One of the country's leading research metallurgists, Dr. Kinzel pioneered in the theory of stainless steel and the theory and application of the structural low-alloy steels and new ferro-alloys. He is responsible for major advances in the welding and cutting of steel. In addition, he spearheaded the research that led to the development of Union Carbide's process for making titanium metal. More than 40 patents have been issued in his name.

Dr. Kinzel is a member of many engineering societies and is past-chairman of the Engineering Foundation Board and of the Welding Research Council. He is past-president of the Engineers Joint Council and chairman of the Engineering and Industrial Research Division of the National Academy of Sciences–National Research Council.

ASTM Sixty-fourth Annual Meeting

Atlantic City, N. J. **Provisional Program** *June 25–30, 1961*

TECHNICAL SESSIONS

MONDAY June 26

MORNING

1 Session on Fatigue

2 Symposium on Soil Dynamics

Technical Session on Electron Metallography

—9:30 a.m.—

Panel Dicussion on Precision and Accuracy and Interlaboratory Testing (Sponsored by Committee E-11 Sub. 2).

AFTERNOON

3 Symposium on Major Effects of Minor Constituents on the Properties of Materials

—4:30 p.m.—

4 Committee Report Session

(Reports A-2, A-7, A-9, B-1, B-3, B-8, B-9, D-3)

—5:00 p.m.—

5 Marburg Lecture
Bruce Chalmers, The Nucleation and Growth of Ice Crystals

EVENING

6 Symposium on Major Effects of Minor Constituents on the Properties of Materials (*Cont.*)

7 Session on Soils

8 Session on Concrete

TUESDAY June 27

MORNING

9 Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service

10 Session on Fatigue (*Cont.*)

11 Symposium on Radiation Effects in Refractory Fuel Compounds

—12:00 noon—

12 Luncheon
Presidents Address and Business Session

AFTERNOON

13 Symposium on Evalution of Metallic Materials in Design for Low-Temperature Service (*Cont.*)

14 Symposium on Radiation Effects in Refractory Fuel Compounds (*Cont.*)

—4:30 p.m.—

15 Committee Report Session

(Reports B-4, B-6, C-4, C-24, D-24, E-3, E-4, E-11, F-1)

—5:00 p.m.—

16 Gillett Lecture
A. B. Kinzel "Specifications?!"

EVENING

17 Session on High Temperature

18 Session on Concrete (*Cont.*)

19 Panel Discussion on Irradiaton Test Methods (*Cont.*)

WEDNESDAY June 28

MORNING

20 Symposium on Extension of Sensitivity for Determining Various Constituents in Metals

21 Symposium on Radiation Effects in Refractory Fuel Compounds (*Cont.*)

22 Symposium on Evaluation of Metallic Materials in Design for Low-Temperature Service (*Cont.*)

—11:30 a.m.—

23 Committee Report Session

(Reports C-8, C-14, C-16, C-18, C-19, C-20, C-21, C-22, D-22, D-23)

—12:00 noon—

24 Awards Luncheon

AFTERNOON

25 Symposium on Extension of Sensitivity for Determining Various Constituents in Metals (*Cont.*)

26 Session on High Temperature (*Cont.*)

27 Session on Steel

Panel Discussion on Nuclear Standardization Activities

—4:30 p.m.—

28 Committee Report Session

(Reports A-1, A-5, A-10, B-2, B-5, D-1, D-5, D-17)

29 Committee Report Session

(Reports C-2, C-3, C-7, C-9, C-12, C-13, D-8, D-18, E-6)

EVENING

Dinner-Dance Entertainment

THURSDAY June 29

MORNING

30 Symposium on Elevated - Temperature Compression Testing of Sheet Materials

31 Session on General Testing

—11:30 a.m.—

32 Committee Report Session

(Reports D-7, D-10, D-12, D-13, E-1, E-12, E-16)

AFTERNOON

33 Symposium on Erosion and Cavitation

34 Session on Non-ferrous Metals

Panel Discussion on the Effect on Materials of Naturally Occurring Space Radiation

—4:30 p.m.—

35 Committee Report Session

(Reports A-3, A-6, B-7, C-15, C-17, D-6, D-14, D-16, D-20, D-25, E-10, F-2, Jt. Comm. Eff. Temp.)

EVENING

36 Session on Cement

37 Session on Road and Paving Materials

38 Symposium on Impurities in Steam

Panel Discussion on Temperature Measurement in the Missile and Space Field
Panel Discussion on District Activities

FRIDAY June 30

MORNING

39 Symposium on Microviscometry

AFTERNOON

—12:30 p.m.—

40 Committee Report Session

(Reports D-2, D-4, D-9, D-11, D-15, D-19, D-26, D-27)

41 Committee Report Session

(Reports C-1, C-11, E-2, E-5, E-7, E-13, E-15, E-17, Jt. Comm. Leather)

—2:30 p.m.—

Bus leaves for post-meeting Bermuda conference

TECHNICAL COMMITTEE NOTES

Metals for Thermostats and for Electrical Resistance, Heating, and Contacts

ONE industry's failures can turn out to be another industry's bread and butter. A case in point: by studying the failures of the welding industry, the electrical contacts industry can learn how to prevent contacts from welding. Such a study has been made, as reported at the meetings of Committee B-4 in February in Washington, D. C. The report, presented by P. R. Lee of Westinghouse Electric Corp., indicated a definite correlation between the weldability of metals and alloys on an ordinary a-c spot welder and the tendency of these same metals and alloys to stick when used in contacts in a switching mechanism. Mr. Lee pointed out that the correlation noted was for heavy parts and large forces in spot welding, but it would be interesting to investigate the situation with delicate wires and small forces. For twelve contact materials investigated, a direct relation was found between electrical conductivity and weld current. Difficulty in welding high-conductivity materials was reported, with silver, copper, and tungsten listed as impractical and silver-cadmium listed as poor.

The committee will publish in its annual report proposed definitions of terms relating to electrical contacts and their use. The list includes such terms as arc, plasma, contact resistance, needle transfer, anodic transfer, and many others.

Contact Seminar and Symposium

The committee has long cooperated with Pennsylvania State University in the holding of an annual seminar on electrical contacts. The annual seminar this year will be held early in June at Penn State.

In addition, the committee is cooperating with several other organizations in the sponsorship of an international meeting on electrical contacts now planned for November 14, 15, and 16 at the University of Maine. Speakers from abroad are being invited. Arrangements are being made by Prof. R. E. Armington, of Pennsylvania State University. After this semester, Prof. Armington will take up new duties on the faculty of the University of Maine.

The committee has about completed a final draft of a bibliography with abstracts relating to thermostat metals. This bibliography will be published by the Society as a Special Technical Publication.

Adhesives

AT A MEETING OF COMMITTEE D-14 held in Washington, D. C., March 16 and 17, the formation of a Subcommittee on Special Adhesives was authorized to cover work on packaging adhesives, shoe adhesives, optical adhesives, and general-purpose adhesives.

Work on wood adhesive test methods is moving forward on a broad front: methods are being developed for lumber adhesives, veneer adhesives, pulp and particle board binders, and adhesives for bonding wood to other materials. A study of dimensional orientation of wood grain angles for the cross-lap shear test was presented. This study will be used as a basis for revisions of the sample preparation in Method D 905.

Metal adhesives methods being finalized in subcommittees are: strength properties of adhesives in shear by compression loading, strength properties of adhesives in shear by tension loading in the temperature range 600 to 1500 F, creep properties of adhesives in tensile shear in the temperature range −67 to 500 F, and preparation of metal surfaces for adhesive bonding.

A recommended practice for the preparation of surfaces of plastics for adhesive bonding is being developed. Existing Committee D-14 methods that could be made applicable to plastics adhesives testing are being reviewed.

A new method of determining the tensile strength of adhesives by the use of rod and bar specimens is being developed. This method will be available as an alternate to Method D 897, which is an old-style approach to the determination of tensile properties. A recommended practice for the preparation of specimens for the bar and rod tests is also being developed.

Plastics

COMMITTEE D-20 on Plastics, at its meeting in Louisville, Ky., early in March, completed action to include in its annual report the following seven new tentatives: a specification for styrene-butadiene molding and extrusion materials; test methods for blocking of plastic film, for coefficient of friction of plastic film, and for apparent density, bulk factor, and pourability of plastics materials; recommended practices for transfer molding of thermosets, for injection molding of polystyrene, and for the sampling of plastics.

The Subcommittee on Plastic Pipe, jointly sponsored with the Society of the Plastics Industry, is adding a new dimensional schedule and additional performance requirements to the specification for rigid PVC pipe. A draft of a specification for PVC fittings, both screwed- and socket-type, is being balloted in the subcommittee. The subcommittee has also come to general agreement on a specification for polyethylene pipe, which it will recommend to the committee for ballot. The specifications for ABS pipe are being revised to include more dimensional and performance requirements. There is a good deal of interest in insert fittings, especially for use with polyethylene pipe, and specifications for this type of product are being drafted.

A new activity in the pipe subcommittee is in nonpressurized pipe, including soil and drain pipe and electrical conduit. Plans are to cover all types of plastics used for electrical conduit in one specification but to prepare separate specifications for the different materials for drain and sewer pipe. The pressure test (D 1599), now applicable only to thermoplastic pipe and fittings, is being reviewed for possible applicability to thermoset pipe, perhaps with some modification.

There is a great deal of interest in the development of working stresses for plastic pipe; one of the problems is the lack of a reliable formula that relates hoop stress to internal pressure. Several formulas have been proposed, but none seems entirely satisfactory.

The committee, having adopted a policy some time ago to convert all its standards eventually to the metric system, is putting this policy into effect. As standards are revised or reset, the style is changed to give preferential treatment to metric units, with English equivalents in parenthesis.

New SBR Rubber

NUMBER 1715 has been assigned to a new styrene-butadiene rubber (SBR) with low water sorption characteristics. Assignment was made by Committee D-11 on Rubber and Rubber-like Materials through its Subcommittee XIII on Synthetic Elastomers, B. S. Garvey, chairman, in accordance with the Tentative Recommended Practice for Description of Styrene-Butadiene Rubbers (SBR) and Butadiene Rubbers (BR) (D 1419–60a T). The description of the new rubber follows:

Number assigned	1715
Date assigned	3/1/61
Requested by	Goodyear Tire and Rubber Co.
Distinctive feature	Low water sorption, 50 PHR oil
Close previous number, if any	
Type	1700
Nominal temperature, deg Fahr	43
Activator	FRA
Shortstop	ND
Antioxidant	NST
Catalyst	OHP
Emulsifier	FA
Nominal bound styrene, per cent	23.5
Nominal conversion, per cent	60
Nominal Mooney viscosity, ML 1 + 4 (212 F), polymer	45
Nominal Mooney viscosity, ML 1 + 4 (212 F), compound	
Coagulation	GA
Carbon black:	
Type	
PHR	
Oil:	
Type	NAPH
PHR	50
Finishing	Special

Note.—Abbreviations and symbols are defined as follows: FRA = free radical type, that is, iron pyrophosphate, peroxamine sulfoxylate. ND = nondiscoloring. NST = nonstaining. OHP = organic hydroperoxide. FA = fatty acid. GA = glue acid. NAPH = naphthenic.

Electrical Insulating Liquids and Gases

THE SENSITIVITY of a test method has been improved and it can now detect an unwanted substance in smaller quantities than ever before. The result: industry is saving large sums of money. The case in point: Committee D-27 has improved the sensitivity of the method for determining water in insulating liquids (D 1533) so that amounts as small as 5 ppm can be detected. This more sensitive method has enabled a closer control of the water content of insulating liquids so that now it is common for deliveries of these materials, used widely in power transformers, to contain as little as 20 ppm of water. This is just about as low as it is practical to dry these hydrocarbon liquids. Reducing water content prolongs the life of the materials and thereby of the transformer, thus saving money both for the utilities and for the consumer of electric power. The same method is also applicable to chlorinated hydrocarbons (askarels) which, because of their lower flammability, are usually used for indoor applications in transformers.

These and other accomplishments of the committee were reported at its meetings in Washington, D. C., March 20–22, 1961.

The committee has developed several field methods for evaluation of insulating liquids, including tests for approximate acidity and polar contamination. The committee has also completed a method for determining coefficient of thermal expansion of insulating liquids useful for measurement purposes where it is desired to determine the weight of a given volume at a certain temperature.

New work on insulating gases is showing progress, with a specification for nitrogen gas for insulating purposes near completion.

Joint Committee on Leather

SYNTHETIC MATERIALS having properties something like those of leather are found to be an increasing threat to leather markets. Fred O'Flaherty, of the Tanners' Council Laboratory, told the Research Committee of the Joint Committee on Leather, at its meeting March 15 in Philadelphia, what to look for in properties of such competitive materials. In consideration of test methods to be used in evaluation of synthetics, there are three distinct areas of interest—serviceability, comfort, and esthetics. Leather, in most instances, is used under dynamic conditions, and therefore dynamic tests are needed to evaluate serviceability. Some of the tests used for evaluating serviceability include abrasion resistance, water absorption, aging, strength, and resistance to mold and perspiration.

A different group of tests measure comfort factors and include fit or adjustability, stretch memory, hand or feel, thermal conductivity, and several others. As for esthetics, there is not only the matter of color and color matching but also the feel of the material and the ability of the synthetic to adapt itself to the styling of the item. He pointed out that the competitive situation of synthetics with shoe upper leather is similar now to the situation that existed when synthetic sole materials of the rubber-resin blend type (Neolite, for example) were introduced. Current statistics on sole leather show that it commands only 28 per cent of the market, the rest being synthetics. He urged the industry, through the members of the Joint Committee, to accelerate its research program and the development of adequate means to evaluate the subtle properties of leather in comparison with competitive materials.

The committee represents not only the interests of industry but also those of the government through active participation by several people from government laboratories. An effort will be made to increase government representation on the committee so that the government specifications and tests for leather in the series KKL-311 might be better coordinated with those of the Joint Committee. It was agreed desirable that the federal test methods for leather and revisions be reviewed by the Joint Committee before promulgation.

The committee took action to increase its scope to cover chemical tests for leather as well as physical tests. When the committee was organized several years ago, it was agreed that the initial emphasis would be on physical tests. The action to expand into chemical tests is dependent upon the approval of the Council of the American Leather Chemists' Assn., which is expected.

The committee completed work on several test methods, including a method for colorfastness and transfer of color in washing, a method for determining

Seen at the meeting of the ASTM-ALCA Joint Committee on Leather held March 15 in Philadelphia are *left to right:* M. M. Baldwin, chairman of Research Committee; R. M. Lollar, chairman of Subcommittee I; and R. Stubbings, chairman of Subcommittee III, Section 5.

perspiration resistance of shoe upper leather, two methods for dynamic water resistance of leather, and a stitch-tear test. Final approval was given to a method for cold crack testing of leather.

The committee plans to meet in August with the Physical Testing Committee of the International Union of Leather Chemists. The meeting to be held on August 19 will terminate a week-long series of sessions involving the International Union. Host for the meeting is the American Leather Chemists' Assn.

Electrical Insulating Materials

CULMINATING SEVERAL years' work, Committee D-9, at its meeting on March 8 in Louisville, Ky., gave final approval to a specification for copper-clad laminates for printed wiring. The committee has completed action on several other recommendations, including methods for thermal stability of insulating varnish, for thermal shock testing of ceramics, and for corona measurement. Also completed is a recommended practice for interlaboratory testing for the evaluation of test methods.

At a previous meeting, Chairman A. H. Scott had asked the subcommittee chairmen to review all the standards under their jurisdiction, with the objective of establishing as American Standard a number of the ASTM standards on electrical insulating materials. As a result of this study, more than ten Committee D-9 standards will be recommended for review by ASA Sectional Committee C59 for approval as American Standard.

"Electrical Insulation Conference" is the new name for the National Conference on Application of Electrical Insulation, which has been held annually in recent years under joint sponsorship of AIEE and NEMA. From the beginning, ASTM members have participated in the technical program. The committee will sponsor a technical session at the conference to be held in February, 1962, and plans are going forward to develop a strong technical program.

ASTM Student Prize Award Program Wins Recognition

THE COLLEGE of Engineering of the Oklahoma State University, in recognition of the Student Prize Award Program sponsored by the Southwest District at this University, has presented the Society with a framed picture of the university campus. The picture is inscribed: "To the American Society for Testing Materials in recognition of valuable and generous contributions to higher education at the College of Engineering, Oklahoma State University."

TECHNICAL COMMITTEE OFFICERS

ADVISORY SUBCOMMITTEE OF COMMITTEE C-8 ON REFRACTORIES

Left to right: F. W. Schroeder, director of research, North American Refractories Co.; L. J. Trostel, General Refractories Co.; W. O. Brandt, secretary, Denver Fire Clay Co.; J. J. Hazel, chairman, Republic Steel Corp.; S. M. Phelps, vice-chairman, Mellon Institute of Industrial Research; J. D. Sullivan, Battelle Memorial Inst.; W. S. Debenham, United States Steel Corp.

OFFICERS OF COMMITTEE A-3 ON CAST IRON

Left to right: R. A. Clark, chairman, Union Carbide Metals Co.; C. F. Walton, secretary, Gray Iron Founders' Society; H. W. Lownie, Jr., vice-chairman, Battelle Memorial Inst.; *not present* W. M. Spear, membership secretary, Worthington Corp.

OFFICERS OF COMMITTEE D-11 ON RUBBER AND RUBBER-LIKE MATERIALS

Left to right: H. G. Bimmerman, vice-chairman, E. I. du Pont de Nemours & Co., Inc.; J. J. Allen secretary, Firestone Tire and Rubber Co.; Simon Collier, chairman, consultant.

ACTIONS ON STANDARDS

The Administrative Committee on Standards is empowered to pass on proposed new tentatives and revisions of existing tentatives, tentative revisions of standards, and the withdrawal of tentatives and standards offered between Annual Meetings of the Society. On March 29, 1961, the Standards Committee took the following action. Anyone interested in securing copies of the standard should write to Headquarters regarding its availability.

Rubber and Rubber-Like Materials

Tentative Method of Test for Specific Gravity of Rubber Chemicals (D 1817–61 T).

New Tentative.—This method is intended for the determination of the specific gravity of solid chemicals used as rubber additives during processing and manufacture.

NEW ASTM PUBLICATIONS

1960 *Proceedings* Now Available

THE 1252-page 1960 *Proceedings* is now being mailed to all members who have requested a copy. Those members who have requested a copy and do not receive it by the middle of June should advise Headquarters.

The 1960 *Proceedings* includes the 1960 Board of Directors' Report, all of the technical committee reports presented at the Sixty-third Annual Meeting, and all of the technical papers accepted for publication in this volume. In addition, the *Proceedings* contains an Author and a Subject Index of all technical papers published by the Society in 1960.

This book is one of the most important publications of the Society. Over the years, the *Proceedings* has been the repository for many technical papers having reference value as the culmination of extensive research projects. This volume records the results of research sponsored by the technical committees and serves as a repository of information concerning other committee activities, including recommendations on standards.

But most of all, the *Proceedings* serves as the one source of information on the work of the Society during the year. It includes reports of meetings and describes the publications that have resulted from those meetings. The Author and Subject Indexes give complete coverage of all ASTM papers, wherever published—*Materials Research & Standards*, *Proceedings*, or in Special Technical Publications. The *Proceedings* is an indispensable reference that summarizes the work of the Society for the year.

Nuclear Methods for Measuring Soil Density and Moisture

STP 293, 105 pages, hard cover, price $4.00, to members $3.20.

AN INTERESTING USE of nuclear methods is described in this symposium volume. The stress in many of the papers is on the techniques to be used in calibrating nuclear instruments. The conventional, direct methods of density measurement are compared with the newer nuclear methods. In addition to the symposium papers, this volume contains a transcription of a panel discussion which considerably enhances its value.

The application of the nuclear soil meter to compaction control for airfield pavement construction has been very successful. The tests conducted, the training of operators, and the precision of the tests are presented.

Soil and foundation engineers have for many years needed a technique for accurate and rapid determination of the moisture content and density of compacted fills. The experiences with nuclear moisture and density surface probes on the O'Hare Field project are described in one paper. By the use of calibration curves prepared specifically for the soil types involved, it is found that the nuclear instruments were reliable and provided a more rapid means of determining the desired information. Another paper compares the results of density and moisture content measurements made on compacted embankments by the nuclear method and by the sand-cone method. This investigation was made by the New York State Department of Public Works. It was concluded that further investigation is necessary in order to ascertain how the nuclear method can be effectively and economically employed for compaction control on projects under construction.

The Highway Research Board was the responsible agency for the administration and direction of the AASHO road test near Ottawa, Ill. The evalua-

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tion of nuclear moisture-density testing equipment was one of the many studies conducted in connection with this road test. This investigation showed that density can be measured satisfactorily by any of the conventional systems or by nuclear density or nuclear moisture gages of the flatiron type. Calibration of the measuring system is extremely important. A suggested evaluation study is included in this publication.

Valuable information is contributed by Mr. Abraham Schwebel, of the National Bureau of Standards, who served as panel consultant on safety precautions.

The contents are:

Design and Application of the Nuclear Chicago d/M Gage—O. K. Neville, Nuclear-Chicago Corp., and T. W. Van Zelst, Soiltest, Inc.

Design and Calibration of a Neutron Moisture Meter—K. N. Burn, National Research Council of Canada.

Application of Nuclear Soil Meters to Compaction Control for Airfield Pavement Construction—P. F. Carlton, Corps of Engineers.

Experiences with Nuclear Moisture and Density Surface Probes on O'Hare Field Project—J. B. Gnaedinger, Soil Testing Services, Inc.

Comparison of Nuclear and Sand Cone Methods of Density and Moisture Determinations for Four New York State Soils—Sidney Mintzer, New York Department of Public Works.

Evaluation of Nuclear Moisture-Density Testing Equipment—W. N. Carey, Jr., J. F. Shook, and J. F. Reynolds, Highway Research Board.

Bituminous Road and Paving Materials

STP 294, 91 pages, price $3.50, to members $2.80.

FEW MATERIALS of unpredictable behavior in use are so widely used as bituminous materials. Information concerning their properties and performance is continually being sought. The papers in this volume make available some of the latest information concerning the properties and performance of bituminous materials and mixtures.

Sand bituminous mixtures, widely used a number of years ago, have received renewed attention lately because of their high degree of skid resistance. One paper in this volume deals with the stress deformation characteristics of such mixtures.

The susceptibility of bituminous materials to temperature changes complicates its behavior and makes it difficult to understand. The effect of compaction temperature on the properties of bituminous concrete is discussed. Increased control of construction procedures has been found essential, as bituminous concrete mixtures are used for heavier and more frequent load applications.

Asphalt rheology—using the fundamental units of stress and shear rate together with the effects of time and temperature—are outlined in a paper which reviews basic flow properties. Microviscometer measurements of various paving and industry asphalts, as well as synthetic asphalts, were used.

The permeability of asphalt concrete pavements to air and water appears to be a primary factor in controlling pavement durability. A method of measuring air permeability is described, both in-place and in cores removed from the pavement.

Two papers discuss emulsified asphalts. One of these concludes that current ASTM specifications in which classification is based on empirical testing not related to construction are inadequate. The author proposes the use of tests of a functional or simulated-service nature. A new type of asphalt emulsion that is receiving increased use is the cationic asphalt emulsion. One paper in this volume describes tests and presents data which have been found useful in evaluating cationic asphalt emulsions. New test methods, as well as modifications of existing methods, will be needed in the evaluation of this type of material. The contents are:

Stress Deformation Characteristics of Sand Bituminous Mixtures—J. A. Carpenter, Standard Oil Company of California.

The Effect of Compaction Temperature on the Properties of Bituminous Concrete—R. W. Kiefer, Cornell University.

A Method for Measuring Air Permeabilities of Asphalt Concrete Pavements—W. H. Ellis and R. J. Schmidt, California Research Corp.

The Influence of Asphalt Composition on Its Rheology—R. S. Winniford, California Research Corp.

Emulsified Asphalt Tests and Specifications—K. E. McConnaughay, K. E. McConnaughay, Inc.

Laboratory Tests and Recommended Specifications for Rapid Setting and Coarse Aggregate Mixing Cationic Asphalt Emulsions—E. W. Mertens, California Research Corp., and L. D. Coyne and E. D. Rogers, American Bitumuls & Asphalt Co.

Plastics

ASTM Standards on Plastics—12th Edition (1961), 1222 pages, hard cover, price $10.00, to members, $8.00

THIS NEW book succeeds the 11th edition, of December, 1959. Heroic efforts were required to keep this book down to handbook size in view of the high output of standards from Committee D-20 on Plastics, the sponsor of this volume. The book contains 25 new items and 29 revisions that were not in the previous book. Among the new items are new tests and specifications relating to cellular plastics, plastic pipe, and such materials as epoxies, urethanes, plastisols, and organisols. One can also find a test to evaluate welding performance of PVC sheeting for welded structures as well as a brand-new test for measuring the tensile strength of plastics under impact conditions.

In order to make room for all this new material, a number of standards only indirectly related to plastics were deleted from the book. For example, tests for folding endurance of paper and tests for evaluating adhesives for resistance to mold and bacterial attack as well as susceptibility to attack by rats are no longer included. Altogether, some 30 items of marginal interest have been deleted.

In addition to the 204 standard specifications, methods of test, and recommended practices included in the book, there are appended the complete personnel of Committee D-20 on Plastics and the committee's regulations and policies on use of the metric system and on writing specifications for plastics.

No plastics laboratory or engineer dealing with plastics can afford to be without the latest edition of this well-known book.

1960 Book of ASTM Methods for Chemical Analysis of Metals

780 pages, cloth cover, price $11.00, to members $8.80.

ALL ASTM TENTATIVES and standards relating to the chemical analysis of metals are included in this publication, which is in effect an unnumbered part of the Book of ASTM Standards and is the only part in which these methods do appear. Of the 61 items included, 20 have been added since the previous (1956) edition, while 23 others have been extensively revised. Methods for the analysis of zirconium, for hydrogen loss of copper powder, and for oxygen in molybdenum cover materials for which there were no methods in the 1956 edition. General recommended practices that have been added since the previous edition include those for interlaboratory studies of methods, probability sampling, choice of sample size, spectrochemical excitation sources, and spectrochemical computations. The recommended practices for apparatus and reagents have been retained with revisions.

A detailed index is provided for maximum utility of the book. Every analytical method is indexed under the metal analyzed and under the element determined. Methods are also indexed under the name of the method for special techniques such as electrolytic or potentiometric.

Adhesion and Adhesives

STP 271, 72 pages, hard cover, price $2.25, to members $1.80.

WITH THE development of new adhesives and new adhesion techniques, there has been a concerted effort by both consumers and producers to develop new applications and new markets for adhesives. The aircraft field began to take an active interest in metal-to-metal adhesives shortly after World War II. Since that time, adhesives have been taking on greater importance in aircraft structures. Other applications of a similar nature, such as in the automobile industry, are being developed.

Committee D-14 on Adhesives pointed up the interest in this growing field by presenting this symposium to help answer some of the many questions raised by design engineers who have sought additional information before using adhesives in their designs.

The contents are:

Introduction—Steven Yurenka, Narmco Industries, Inc.

Lap-Shear and Creep Testing of Metal-to-Metal Adhesive Bonds in Germany—Karl F. Hahn, Douglas Aircraft Co.

Elevated-Temperature-Resistant Metal-to-Metal Adhesives Derived from Organic-Inorganic Polymer Systems—Edward C. Janis, Narmco

Preliminary Evaluation of Ceramic Adhesives for Stainless Steel—L. E. Gates and W. E. Lent, Hughes Aircraft Co.

Tensile Shear Strength of Adhesive-Bonded Metals as a Function of the Rate of Loading—Desmond A. George and John Mandel, National Bureau of Standards, and Harry R. Butzlaff, A. O. Smith Corp.

Bonded Metal-to-Metal Testing—Lee R. Lunsford, Convair Div., General Dynamics Corp.

Emission Spectrochemical Analysis

ASTM Standards on Emission Spectrochemical Analysis—Third Edition (1960), 704 pages, cloth cover, price $11.00, to members $8.80.

THE METHODS FOR spectrochemical analysis that have been found most satisfactory by industry are included in this latest edition of Methods for Emission Spectrochemical Analysis. Sixty-four methods provide an extensive coverage of all current techniques for the spectrochemical analysis of metals, including the metals that have more recently gained prominence, such as titanium and zirconium.

Spectrochemical analysis of nonmetallic materials is provided in 36 methods which cover a wide variety of materials, such as refractories, ceramics, glass, cement, caustic soda, metal oxides, ores, slags, plating solutions, industrial water, polyols, and petroleum products.

Fifteen recommended practices cover techniques applicable to spectrochemical methods in general, from the choice of sample size through plotting of curves, computations, and statistical evaluation of data.

This book should be of value to all persons concerned with spectrochemical analysis.

A Five-Attribute System of Describing Visual Appearance

By Deane B. Judd, Photometry and Colorimetry Section, National Bureau of Standards.

STP 297, 24 pages, paper cover, price $1.00, to members 80 cents.

THE author begins this comprehensive paper with a discussion of the common usage of the term "color," which is generally described in the three-attribute system: hue, saturation, and lightness. He then gives several examples of the inaccuracy of the three-attribute system for color appearance description. For example, he cites the distinction between gold and yellow and that between copper and reddish brown. He points out that these distinctions are not wholly a matter of gloss, because a gold surface may be depolished until it has the same gloss as that of a glossy yellow paint of the same hue, saturation, and lightness, and yet the appearance of the two surfaces will be very different. These difficulties have long been recognized and investigated. One result of these investigations is the drawing of the distinction between the various modes of visual appearance.

The paper discusses in detail the nonshape, nontextural aspects of visual appearance classified according to the following four modes of appearance: aperture, illuminant, volume, and surface modes. Each of these have different attributes. The relation between these attributes is discussed, and a short list of appearance descriptions is included as a demonstration of the inclusiveness of the system.

The author points out that while present-day knowledge of visual appearance is considerable, it is far from complete. The five-attribute system of classifying the nonshape, nontextural aspects of appearance accordingly is adequate to the description of a considerable portion of visual appearance, but not to all. The author states that other systems are possible, each one having different but equally unavoidable arbitrary features.

The author makes a very clear and understandable presentation of this rather difficult and complex subject of color and color measurement. The paper includes detailed definitions of the various terms used and discusses the interrelations among the various color attributes. This publication will be a valuable reference for anyone interested in visual appearance of materials.

Research Forum Copies Still Available

A FORUM, "The Place of Research in ASTM," sponsored by the Society's Administrative Committee on Research, was held at the Annual Meeting of the Society in 1959. Copies of the proceedings of the forum are available free on request as long as the supply lasts. Included are remarks of officers and members of the Administrative Committee on Research, officers of the Society, and a general discussion. The report summarizes the activities of the ACR from the time of its organization in 1924 to the present. It also assesses the importance of research in ASTM.

Next month in *MR&S*...

Information Retrieval

IF YOU are planning an information retrieval system, before you freeze your plans, make sure that you know about the types of systems available and whether the system you select will be adaptable to changing conditions. Equally important is a clear understanding of the difference between data and information and the operations and processes by which they may be handled. The physical form of the storage system is secondary to the fundamental issue—the problem it is expected to solve and the approach selected. Orient the system around the user even if it means less convenience and more work for you in putting information into it.

Watch for some helpful tips on this subject in next month's *MR&S* when John C. Costello, Jr., presents "Some Thoughts on the Information Storage and Retrieval Problem."

Mr. Costello until recently was Senior Information Systems Engineer, Engineering Department, E. I. du Pont de Nemours and Co., Inc.

MATERIALS SCIENCES

AEC Research in Metallurgy and Materials

A TECHNIQUE FOR cooling metals at extremely high rates, high enough to prevent the normal processes of nucleation and growth of equilibrium phases, has been developed at the California Institute of Technology, with the support of the Atomic Energy Commission. Use of the technique contributes to an understanding of the fundamental nature and behavior of solids. It involves the propelling of a small liquid droplet (about 25 mg), by means of a shock wave, against the inside surface of a high-speed rotating copper cylinder. Under these conditions, silver and copper, which normally form the eutectic, form a solid solution. The technique enabled the discovery of a new compound, silver germanium, with the approximate composition, Ag_3Ge.

High-Pressure Research.—Shock pressures and associated compressions of 19 metals have been measured at Los Alamos Scientific Laboratory to about 2,000,000 atmos. The pressure-compression curves were used to determine a complete high-pressure equation of state for each metal. Such an equation of state, if developed to the ultimate, might permit calculation of the properties of a given substance under any set of conditions.

The above projects and many others were described in a special report of the U. S. Atomic Energy Commission entitled *Atomic Energy Research in the Life and Physical Sciences, 1960*. The report is available from the Superintendent of Documents, Washington, D. C.

The Mole Changeth

EVER SINCE the discovery in the late 1920's that oxygen exists in three isotopic forms, 16, 17, and 18, the physicists have used $O^{16} = 16$ as the basis for their atomic scale. The chemists' scale, using all three nuclides in natural occurrence as "16," differed from that of the physicists by 1.000275. For years the two groups tried to agree on a common scale, and it was only recently that the efforts were successful. The new atomic scale officially endorsed by the International Union of Pure and Applied Physics in 1960 is based on $C^{12} = 12$. The International Union of Pure and Applied Chemistry had agreed in 1959 to introduce the scale at its meeting this summer in Montreal, contingent on the action of IUPAP to endorse the scale.

The table below is a comparison of the new unified scale with the two obsolete scales for a few selected elements.

The change for chemists is only 43 ppm—a very small change, indeed, but it represents a great triumph of reasonableness over confusion. The change also provides an occasion for tidying up nomenclature related to the scale. The term "atomic weight" has long been confusing to the student: it is hard to explain that this is not weight of an atom. It is hoped that the term will fall into disuse. A number of recommendations for improvements in notation and nomenclature have been endorsed by the international unions of physics and chemistry as well as by ISO/TC 12 on Quantities, Units, Symbols, Conversion Factors, Conversion Tables.

Adapted from "The Mole and Related Quantities," by E. A. Guggenheim, *Journal Chem. Ed.*, Vol. 38, No. 2 (1961).

Element	Old Physical Scale	Old Chemical Scale	New Unified Scale
O^{16}	16 exactly	15.99560	15.99491
O	...	16 exactly	15.9999
C^{12}	12.00382	12.00052	12 exactly
C	...	12.011	12.010
Ag	...	107.880	107.868

DISTRICT ACTIVITIES

CLEVELAND

MORE THAN 65 members of the Cleveland District met at dinner at the Cleveland Engineering Societies Building on Thursday, March 30, 1961, for an evening with A. Allan Bates, president of ASTM, and Thomas A. Marshall, Jr., executive secretary.

Student awards were made to three students from Fenn College and three from Case Institute of Technology. Mr. Marshall presented the certificates after a brief talk in which he stressed the importance to young engineers of active participation in the work of technical and scientific societies.

Dr. Bates discussed the industrial development in the Soviet Union and the effects on the Soviet people and their economy of the decision of the revolutionary leaders to industrialize. As a result of this decision, the Soviet economy has been changed drastically in the past 40 years from a rural economy to an industrial or urban economy. As part of this change, it was necessary to provide homes to move nearly 100 million people from farms to cities. Dr. Bates' talk was illustrated with slides taken by him on his visit to the Soviet Union last August as the chief of a U. S. delegation visiting the Soviet Union to study its construction methods and accomplishments.

Toastmaster for the evening was Mr. A. G. Gray, chairman of the Cleveland District Council.

AT THE CLEVELAND DISTRICT MEETING.

WASHINGTON, D C.

ASTM PAST, present, and future was the theme of a talk presented by Vice-President Miles N. Clair at a joint meeting of the Washington District of ASTM and the Raleigh Engineers Club in Raleigh, N. C., on April 10. Mr. Clair's historical review of ASTM, starting with the original participation in the International Association for Testing Materials, was liberally sprinkled with engaging anecdotes. In the latter part of his talk, Mr. Clair stressed the broad opportunities that will be available, not only to the standards-writing bodies but to all engineers, in the use of the knowledge of the many new materials now finding application in our space vehicle program. This knowledge will be valuable later when such materials are available for more mundane purposes. Mr. Clair discounted the feeling so often expressed by the man on the street that Russia is ahead of the United States and that we cannot hope to catch up. He closed with emphasis on the fact that the human being is still a very vital factor in all scientific work.

A brief review of the new activities of the Society during the past year, including the formation of new technical committees, was given by L. C. Gilbert of the ASTM staff.

Those present from the Raleigh Engineers Club were very receptive to the program, since it has been the purpose of their meetings to learn about other societies and national organizations. C. E. Proudley and J. E. Wood, both vice-chairmen of the Washington District, were present, with Mr. Proudley serving as host chairman.

Asphalt Conference

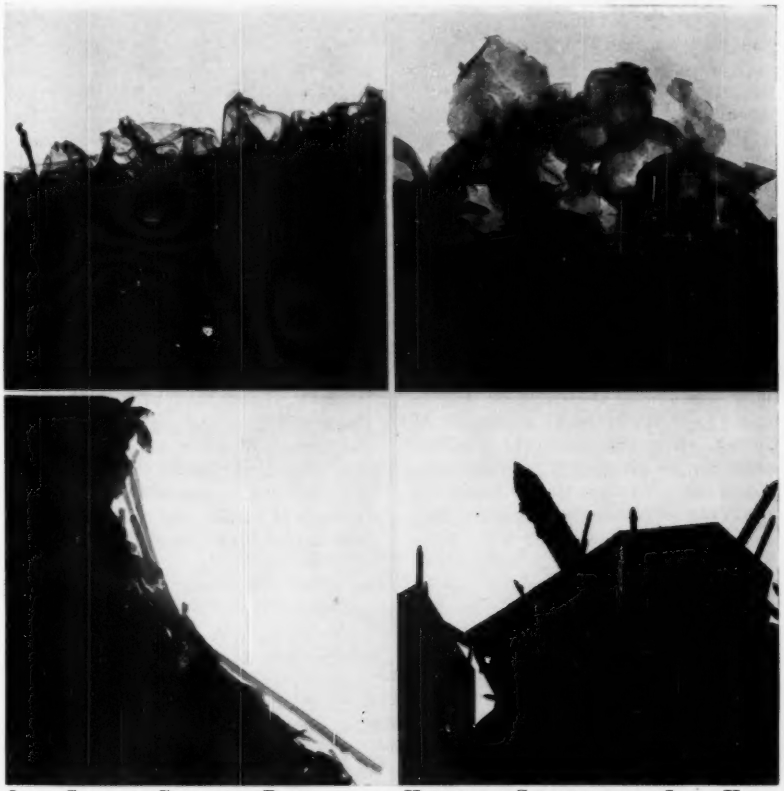
AN INTERNATIONAL Conference on Structural Design of Asphalt Pavements will be held at The University of Michigan, Aug. 20–24, 1962. It will be sponsored by the Department of Civil Engineering with the cooperation of the Asphalt Institute.

The conference will cover both the design and field performance of asphalt pavement structures. Papers and discussions will report specially designed road tests, investigations of pavements in service, and laboratory and theoretical studies. The conference is timed to follow the release of the AASHO road test results and will provide the opportunity for review, discussion, and critical analysis of these data.

Further details may be obtained from Prof. W. K. Parr, Department of Civil Engineering, University of Michigan, P. O. Box 619, Ann Arbor, Mich.

ASTM MEETINGS

Date	Group	Place
June 4–9	Committee E-14 on Mass Spectrometry	Chicago, Ill.
June 9	Committee E-19 on Gas Chromatography	Chicago, Ill. (Sherman)
June 13	Northwest District (Joint with Am. Soc. of Mechanical Engineers and Am. Soc. for Metals)	Richland, Wash.
June 25–30	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**
August 15–18	Joint ASTM-TAPPI Committee on Petroleum Wax	Montreal, P. Q.
August 19	Joint Committee on Leather and Physical Testing Committee of International Union of Leather Chemists	Washington, D. C.
	1962	
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler Hilton)**
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, P. Q. (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**



IRON SULFIDE CRYSTALS: REACTION OF HYDROGEN SULFIDE WITH IRON USING PFEFFERCORN TECHNIQUE

The crystals grew about the periphery of a 150-μ hole in a pure iron disk. The disk was exposed in water saturated with hydrogen sulfide for periods ranging from 2 min to 24 hr. Electron diffraction analysis indicated the first crystals formed had different lattice spacings from any of the known iron sulfides. Kansite, Fe_9S_8, formed after 1 hr. Time of exposure to hydrogen sulfide: upper left, 2 min; upper right, 15 min; lower left, 1½ hr (magnification 50,000X); lower right, 24 hr (magnification 15,000X, reduced for publication). Twelfth ASTM Photographic Exhibit. Honorable mention, electron micrographs, technique. A. W. Bartunek, D. H. Oertle, and F. G. Rowe, Continental Oil Co., Ponca City, Okla.

ACR NOTES ADMINISTRATIVE COMMITTEE ON RESEARCH

High-Speed Micrography, a Continuing Problem

By J. S. COURTNEY-PRATT[1]

IN A GREAT many problems in research and industry today, it is necessary to take pictures with a very short exposure time to study what is happening—to see how certain kinds of faults occur, or to see whether equipment is behaving as it should. The exposure time that is needed is dictated partly by the speed of the object and partly by the relative size of its image in the camera. If we are photographing, for example, a car traveling fast, we might need an exposure time for any frame between 0.01 and 0.001 sec. Suppose the car is traveling at 100 mph across the line of sight and that it is 75 yards away. If we have a camera that takes pictures of the same size as a professional 35-mm motion picture camera, each frame will measure 16 by 22 mm. With a lens of 6-in. focal length, the image of the car will be about half as long as the frame, and the speed of the image relative to the emulsion will be only $\frac{1}{450}$ of the speed of movement of the car. If, to distinguish the detail we want, we decide that the image blur should never be more than 0.1 mm, we would obviously need an exposure time as short as 0.001 sec. If the car is more distant or moving toward the camera rather than across the line of sight, the exposure time will not need to be so short. It is because the car is a large and relatively distant object that we get sharp pictures at normal exposure times.

Suppose, however, that we want to study the deformation of a coil spring. We may wish to examine detail that is only a few tenths of an inch across. We would need to take pictures at something near natural size rather than reduced by a factor of 450, and the rate of movement of the image in the camera would be then 450 times faster. The exposure time that we would need would have to be 450 times briefer.

The extraordinary shortness of the exposure time that is needed when we begin to study fine detail is quite a general problem. It is greatly aggravated when we consider the problem of taking pictures through a microscope. Suppose we wished to study the leg movement of a fly. It can walk at, say, 1 or 2 ft per sec. We might well wish to magnify an image of its foot by a thousand times; and so the image on our film would be moving (intermittently) at speeds higher than 1000 ft per sec. To keep the blur on the film to the same figure as before, that is, 0.1 mm, we would need an exposure time shorter than a three-millionth of a second.

When we are studying faster phenomena such as detonation, explosion, deflagration of solid and liquid propellents, atomization in a carburetor, the grinding or cutting of metals, the penetration of armor plate, the formation of electric sparks, the "explosion" of a thin wire by a surge of current, the fracture of brittle materials, the vibration and fatigue of metals, the formation of shock waves, the ablation of hypersonic projectiles—to name but a few examples—the rates of movement are much higher and the significant detail is often just as small. In such cases it is more than ever necessary to make use of the most sophisticated and ingenious cameras.

There are three main types of cameras that have been used to take sequences of pictures through a microscope. All three will give a resolution of 200 to 300 lines across the frame in each dimension. The best known is the rotating-prism type, like the Fastax camera. It can take very long sequences of pictures at about 10^4 per sec with normal frame height, and at twice this speed for half-height frames. Image-dissection micrographs have been built that can record a sequence of about 300 frames at 10^5 frames per sec. Rotating-mirror framing cameras like the Beckman and Whitley Model 189 can take a sequence of 25 pictures at a rate of just over 10^6 per sec. Thus, we can have a long sequence at 10^4 frames per sec, a few hundred frames at 10^5 per sec, or a short sequence at 10^6 per sec. It would be a great advantage in many fields of research if we could get more frames and higher rates and better resolution per frame.

The factors to be considered in making a choice among the various types of available equipment underline a general problem in high-speed photography. In spite of the many recent advances, it is not possible to obtain a single camera that has wide-aperture lenses, that runs at a very high speed, that works at a high magnification, and that gives extremely brief exposures and a high resolution, all in the same instrument. This all emphasizes the need for continued research and development effort in the whole field of high-speed photography.

[1] Bell Telephone Laboratories, Inc., Murray Hill, N. J.

MATERIAL QUESTIONS

NEARLY EVERY day the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing or research laboratory is obviously required; in this event we do not hesitate to so recommend.

Bronze for Steam Valves

Can you tell me where I might find data on the mechanical properties of cast bronze suitable for steam valves? Service temperatures will be from 100 to 500 F, possibly as high as 600 F.

● Two papers published recently by ASTM may be of help. The first is "The Creep Properties of Three Low-Shrinkage, Copper-Base Casting Alloys," by W. F. Simmons and J. G. Kura, ASTM *Proceedings*, Vol. 58, p. 791 (1958). The second paper, "Mechanical and Physical Properties of Five Copper-Base Casting Alloys," will be published in the 1960 ASTM *Proceedings*.

The cast bronzes used most prevalently in the valve industry are covered in the ASME Boiler and Pressure Vessel Code in the 1959 Section VIII on Unfired Pressure Vessels. Working stresses for the bronzes under ASTM Designations B 61 and B 62

are to be found in the table UNF-23, pp. 92 and 93. Stresses for B 61 are covered up to 550 F and for B 62 up to 400 F.

Oil for Rice Polishing

Would you kindly tell us what chemical products could be added to the technical white oil used to color rice? It must be nothing harmful, and it would not matter if it coated the color of the grains with a polished effect.

● We are not aware of the practice of coloring rice granules with a solution of dye in a technical white oil. The only use of white oils in this type of application that we know of is for polishing or lubricating rice or macaroni products. In this case we recommend not a technical white oil but rather one meeting fully U.S. Pharmacopoeia or National Formulary purity specifications.

NBS Issues Luminance Standards

LUMINANCE STANDARDS to calibrate meters used by illuminating engineers and by manufacturers of aircraft instrument panels to evaluate "brightness" are now available from the National Bureau of Standards. With the aid of these standards, uniformity can also be achieved in measuring the luminance of other products, such as cathode ray tubes. The standards are issued with a report of calibration containing instructions for their use. They can be procured from the Photometry and Colorimetry Section, National Bureau of Standards, Washington 25, D. C.

Metallo-Organic Standards Available from NBS

TECHNOLOGICAL ADVANCES have created an ever-increasing need for standard and reference-type samples. As the result of such a need, the National Bureau of Standards has developed, and is now supplying, 24 new metallo-organic analytical standards. These reference standards were developed for use within the petroleum industry by a project at the Bureau supported by the American Petroleum Inst. However, they can be used wherever metallic constituents in the form of oil-soluble complexes must be measured quantitatively.

The standards provide a convenient means for calibrating instrumental methods of analysis and are valuable in the development and subsequent control of analytical methods for metallic components. Each standard is provided with a certificate of assay, the nature of trace metallic impurities, stability, compatibility, and directions for preparing oil solutions. They are available in 5-g lots at $6. Further information may be obtained from the Standard Sample Division of the Bureau.

Museum of the History of Science, Florence

Bumel's Praetorian Table

This unusual type of *vade mecum* contains not only several different instruments, but also a book describing their uses. Blank pages in the book serve as a Praetorian (Plane) Table, being used in conjunction with the sighting device and clinometer seen in the front of the instrument. On the top there is a divided circle with a magnetic compass, also for use in plane table surveying. At the center of the compass, so as to make more use of it, there is a little horizontal sundial. The instrument itself was made and signed by Michael Bumel of Nuremberg, 1625. He is known for several other measuring and survey instruments. The book is by Andreas Albrecht, a distinguished Nuremberg surveyor. It explains the multitudinous uses of this device on land and at sea as well as in the art of perspective drawing. The instrument is preserved in the Museum of the History of Science, Florence.

Text by Professor Derek J. de Solla Price, Yale University.
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ASTM Specifications in the Southern Standard Building Code

By M. L. CLEMENT[1]

Building Code Organizations . . .

Preparing a building code for a muncipality is a big job, as anyone who might try to prepare one from scratch would learn. Fortunately, this isn't necessary; there are four national and regional codes, prepared through the pooled efforts of local building officals, that can either be adopted *in toto* or with modifications.

This article tells how one of these code groups uses ASTM standards. The other three groups and their publications are: Building Officials Conference of America—*Basic Building Code;* Midwest Conference of Building Officials—*Modern Standard Building Code;* International Conference of Building Officials—*Uniform Building Code.*

AN ARCHITECT in Shreveport, La., drawing up specifications for a school building, will make certain that they call for brick conforming to ASTM Specification C 62, C 73, or C 55, depending on the type and grade wanted; he will also specify ASTM standard cement C 150, tile C 34, gypsum C 22, and lime C 141. The same thing happens in Norfolk, Va.; Wichita Falls, Tex.; Knoxville, Tenn.—in fact, all over the country. But what is special about the Shreveport architect's choice of ASTM standards is that they are an integral part of the Southern Standard Building Code, now adopted by 982 municipalities.

Why is a Southern Code necessary? What are its aims, its objectives, its accomplishments?

A little more than a decade ago the South had a crazy-quilt pattern of conflicting building regulations. No two cities had the same building code. Most municipalities had building laws that were totally unrealistic. Furthermore, there was no permanent machinery to advance a modern code in the South.

Most of the old building codes had been put together, usually under the supervision of "traveling experts," by combining bits and pieces from a good many other codes, many of which had been put together in the same manner in the first place. This kind of patchwork resulted in a code for Tampa, Fla., that provided for Massachusetts snow loads; and a Birmingham, Ala., code contained provisions for earthquakes borrowed from West Coast codes. Such nonsense prevented the economies made possible by building for the South's benevolent climate. Architects and engineers were frantic as they tried to design in various cities under divergent and unworkable building regulations.

Many cities wanted to break this stranglehold on their progress, but no one municipality could bear the cost of the research, engineering, correlating, printing, and publishing necessary to produce a modern building code. In 1941 a few municipalities got together to do something about it. The Southern Building Code Congress was the result. The first edition (1945) of the Southern Standard Building Code was produced by spreading the cost among the cities forming the Congress.

The Southern Building Code Congress, a municipal association, is dedicated to constant research aimed toward improving the Southern Standard Building Code with regular revisions. It has educated cities in updating their code to take advantage of new developments.

In 1945, when the first Southern Code was published, there were only three adoptions. Since that time it has continually gained wider acceptance, until today there are 982 adoptions. Cities now realize that it is no longer necessary for their building progress to be hamstrung through obsolescence.

The Southern Code has used standards of ASTM exclusively since its inception. ASTM is continually updating and improving its standards, and our provisions are continually correlated with the latest standards produced by ASTM. The Southern Code follows performance criteria as closely as possible; material that can be qualified by proper tests as meeting these criteria can be accepted under the code. It must be seen, therefore, that ASTM performs a very valuable service for the Southern Building Code Congress in providing proper test standards for materials and in keeping these standards constantly abreast of new developments in material and construction techniques.

On the matter of fire rating, it is particularly significant that ASTM deals only in fire test procedures and, so far, has not attempted to establish any building code end points for qualified materials under the test. The establishing of such end points is a proper function of bodies such as the Southern Building Code Congress, which can approach the problem from a qualified and impartial point of view. The congress has had excellent support from industry. No organization that is wholly supported by industry could promulgate a building code and keep its autonomy. Such a code would favor that industry and thus lose the confidence of the building officials and city authorities.

ASTM sets national standards for performance of materials through a well balanced committee setup composed of outstanding men in their respective fields of industry. American industry as a whole lives up to the criteria of manufacturing established by ASTM standards. By setting up such qualifications on an impartial basis, the public safety has been guarded in this nation.

[1] Executive Director, Southern Building Code Congress, Birmingham, Ala.

Temperature Symposium Attracts Scientists from U. S. and Overseas

TEMPERATURE, A key factor in recent advances in controlled fusion experiments, rocket, missile and high-speed aircraft research, radiation measurements in nuclear reactors, and in many industrial processes, was the subject of a five-day scientific meeting at Columbus, Ohio, March 27–31.

Three of the nation's scientific bodies, the American Institute of Physics, the Instrument Society of America, and the National Bureau of Standards, all concerned with temperature measurement in science and industry, sponsored the 228 technical presentations covering advances in research and development.

This was the fourth major scientific meeting devoted to the measurement and control of temperature in science and industry, with emphasis on new frontiers in research. The first was held in 1919, the second in 1939, and the third in 1954. The proceedings of the 1939 and 1954 meetings have been published by Rheinhold Publishing Corp. and have become basic reference works in the field. The proceedings of this symposium will be published also.

In his introductory remarks, Allen V. Astin, director of the National Bureau of Standards, said, "The key problems right now are defining, measuring, and controlling temperatures at very high and very low regions of the scale."

At the very high level come astrophysical problems of space exploration, efforts to control thermonuclear energy, and the materials for industrial processing. "So far," said Dr. Astin, "we don't even have a very good definition of what very high temperature means, except that it is higher than something else."

"At the other end of the scale, as we approach absolute zero," he explained, "all motion tends to cease and we have a remarkable opportunity to study the basic properties of matter. Matter has other intriguing properties at this level—for example, electrical resistance tends to vanish—and we haven't done much yet about utilizing these properties."

The symposium explored the increasing role of temperature measurement and control in the physical, biological, engineering, and medical sciences. The program was divided into major areas of interest, namely, definitions of temperature and establishment of temperature scales, principles and applications of various measuring instruments, and applications of measurement methods in various special fields.

General chairman of the symposium was William A. Wildhack, National Bureau of Standards.

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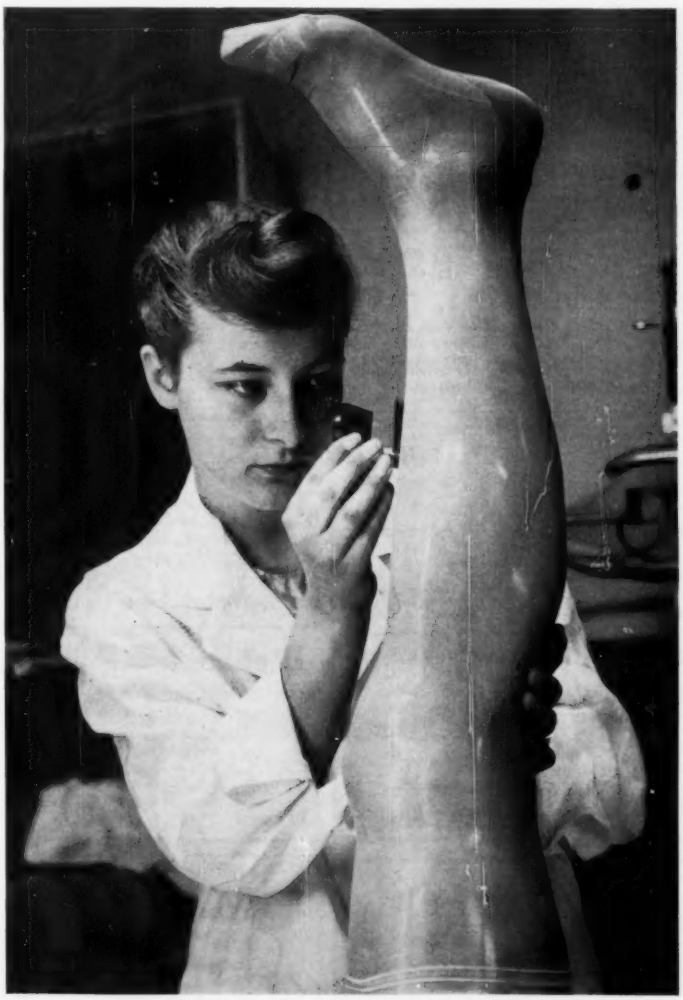

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Small print

This little file holds some 10,000 unabridged pages of technical reports of the French Atomic Energy Commission. The lady who lives in the house across the road may find this astonishing. Your boss may be astonished. Even you may be astonished. But to the reasonably alert librarian the micro-opaque card idea is old hat. Anything we can tell you about it your librarian can tell you better.* We merely draw attention to the following accretions to the available micro-opaque literature:

• *All* the unclassified scientific reports released by the U. S. Atomic Energy Commission.

Even reduced 20× as they are in micro-opaque form, the complete set published to date would fill 250 boxes like the one above. The indexing mechanism for this incredible mass of information is *Nuclear Science Abstracts*, a periodical sold by the Superintendent of Documents, Washington 25, D. C.

• Reports of the Commissariat à l'Energie Atomique.

Naked-eye abstracts in French and English on the front of each card, the complete paper in microform on the back. Sold at 50¢ per card by Microcard Editions, Inc. (901 26th St. N. W., Washington 7, D. C.), who will explain indexing system.

• The 1st Decennial Index to *Chemical Abstracts*, the brilliant chemical years 1907 to 1916.

Contains the roots of many a chemical concept since proliferated beyond the scope of a single mind. On some 60 3" x 5" cards sold by the American Chemical Society (1155 16th St. N. W., Washington 6, D. C.).

• *Justus Liebigs Annalen der Chemie* from 1832 to 1958 and *Berichte der Deutschen Chemischen Gesellschaft* from 1868 to 1958.

The New Testament comprises four Gospels; the science of chemistry seems to be founded on only three gospels, less influential spiritually but vastly more voluminous. Microprint overcomes the voluminousness but accomplishes nothing spiritually. The third gospel, *Beilstein*, got the treatment earlier. Microcard Editions, Inc.

• *The First Six Million Prime Numbers.* 1 (controversial) to 104,395,289.

Result of a 4-day holiday weekend with a large computer and nothing better to do than a favor for mathematicians working in number theory. Microcard Editions, Inc.

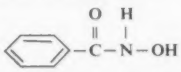
For any sustained use of micro-opaques, you need a micro-opaque reader. Ten years ago they were rare. Today the central research library that lacks one is rare. Any scientific discipline that needs to communicate large masses of data to a limited number of its disciples should consider microprint. For suggestions on how to proceed, write Recordak Corporation, 415 Madison Avenue, New York 17, New York (Subsidiary of Eastman Kodak Company).

*The reason *we* try to tell you is that we want to sell the raw photographic materials on which microprint cards are printed. We also want to sell microfilm. The librarian can tell you about *that*, too. A new conventional-sized reference, "Guide to Microforms in Print" ($4, Microcard Editions, Inc.), summarizes everything available.

That new calcium reagent? Sure!

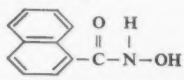
The following proves that we are human. Frankly, we would much prefer to be regarded as a benevolent but flawless machine, incapable of error. It looks nicer.

But since you insist on reading on into the details, consider *Benzohydroxamic Acid* (Eastman 8262), a reagent of broad analytical utility. This compound forms a brilliant red color on chelation with ferric chloride, colorless salts with the alkali metals, and colored chelates with many polyvalent metals such as uranium and vanadium. Its structural formula is



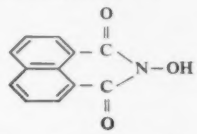
and it had held our attention. At this time our attention was also drawn to a preconvention abstract of an analytical paper on a new reagent for traces of calcium in steel and sodium. The calcium reagent was designated naphthalhydroxamic acid.

This, we mumbled to ourselves, figures—a homolog—



So we made it. The paper was duly presented at Pittsburgh by a representative of the chemical company where naphthalhydroxamic acid had proved useful. Recognizing our cherished role as intermediary between laboratories where a reagent is discovered and laboratories which want to try it, a chemist from another chemical company immediately made inquiry to us. We showed him our new homolog. He ordered some, went home, tried it, and found it worthless for the purpose. You, of course, realize why.

Our homolog is *1-Naphthohydroxamic Acid* and was so labeled. But who brought up the homolog jazz anyway? We did. The man wasn't suffering from a speech defect or a typographical error when he said naphthalhydroxamic acid. It was we who were suffering from the disease that causes jumping at conclusions. He meant the reaction product of hydroxylamine with naphthalic anhydride, viz.



Abashed, we slunk back to the bench and made that. Another goof here would be most unbecoming. The man who called it naphthalhydroxamic acid had said it was white. What color was ours? Yellow. Yellow, eh? Stall! Don't ship! Give any excuse, but don't ship! And we dug into the literature. Even dug up an old paper that speculated about what it called "xanthoisomers" of certain phthalic oximes otherwise structurally identical.

Our product *did* give the proper infrared absorption spectrum and melting point. It *did* give an excellent test for Ca^{++} when used in a procedure in *The Analyst* (Dec. '60). This paper described the compound as yellow. A Japanese paper was also found that described it as yellow.

Confidence slowly returned. Under the name *N-Hydroxynaphthalimide* and the designation Eastman 8161, we are now releasing it and even offering procedural abstracts. Also offered is the ill-begotten *1-Naphthohydroxamic Acid* as Eastman 8030. It may be good for something.

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BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and the subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Precision Measurement and Calibration—NBS Handbook 77

Vol. I, Electricity and Electronics, 845 pp., $6.00.
Vol. II, Heat and Mechanics, 965 pp., $6.75.
Vol. III, Optics, Metrology, and Radiation, 1025 pp., $7.00.
Set of Vols. I, II, and III, $19.75. Compiled by the National Bureau of Standards and available from the U. S. Government Printing Office, Washington, D. C.

Adapted from publisher's description.

THE NATIONAL BUREAU of Standards has selected for this three-volume compilation its more important publications dealing with precision measurement and the calibration of standards. These publications were originally issued over a period of years as circulars, research papers, chapters of books, and articles in scientific periodicals, and, as separate documents, best served the needs of scientists working in specialized fields of measurement who hitherto made up the principal audience. Now, however, the great increase in industrial activity, particularly in the missile and satellite field, has led to an unprecedented demand for precision measurement, which, in turn, is bringing about the creation of hundreds of new standards laboratories. Since most of these new laboratories must cover the entire field of measurement, and must do so with a staff not previously trained in work on standards, there is an ever-increasing need for a compilation of pertinent published information on this subject.

To meet this need the Bureau has selected for this compilation those publications that have been referred to most frequently in conferences between its staff members and persons engaged in establishing new standards laboratories.

Extensive as they are, these three volumes include only a fraction of the published work of the Bureau relating to standards. Many of the papers that are reprinted contain extensive bibliographies which will enable the scientist or engineer who is confronted with a special problem to locate additional publications both by the Bureau and from other sources that bear on his problem.

This three-volume handbook for workers in the field of standards is comparable to the familiar handbooks of chemistry, physics, and engineering. It will also serve as a reference and textbook for hundreds of young scientists and engineers who must acquire training in the shortest possible time to fill responsible positions in new standards laboratories.

Boron—Synthesis, Structure, and Properties

Edited by J. A. Kohn, W. F. Nye, and G. K. Gaule; Plenum Press, Inc., New York, N. Y. (1960); 189 pp.; $8.50.

Reviewed by L. L. Wyman, National Bureau of Standards.

THIS BOOK consists of 21 technical papers presented at the 1959 Conference on Boron held under the sponsorship of the Institute for Exploratory Research, U. S. Army Signal Research and Development Agency. The conference (and consequently this book) was restricted to but three phases of boron interest: preparation and crystal growth, structure and bonding, and certain of the physical properties of the metal, especially those optical and electronic in nature.

More than half the papers deal in some measure with the preparation of high-purity boron, and most of these are involved with the "hot-wire" decomposition of one of the halides, several detailed descriptions of the process being given. From these, one gathers that the best way to obtain this metal at a purity level of 99.9+ per cent is by the thermal decomposition of $BBr_3 + H_2$ on a tantalum wire at about 1460 C. This technique has been used to deposit boron on graphite, tungsten, molybdenum, and rhenium, the tungsten and molybdenum wires being prone to contaminate the boron. Tantalum, too, reacts with the deposited boron, and a boride layer is formed. However, some techniques permit the physical extraction of a Ta + TaB core, leaving a tube of pure boron for subsequent treatment.

Among the other methods of preparation, one notes the commercial production of 95 to 99 per cent material by the thermal decomposition of BCl_3 on graphite; the production of 99.8 per cent metal by the electrolysis of $KBF_4 + B_4C$; and metal of a 99.1+ per cent quality obtained by magnesium reduction of B_2O_3 with subsequent chemical purification and vacuum heat treatment. BI_3 is also amenable to pyrolysis for the production of pure boron.

Boron purification is of concern in several of the papers, most of which employ some form of zone refining either as floating zones or, in one instance, by the conventional "boat" method using r-f heating of the metal contained in a boat made from boron nitride. Additionally, one author uses vaporization at 2000 C in very low vacuum as a means of purification and formation of boron cyrstals.

The complex polymorphism of boron is well recognized, the basic forms being the low-temperature alpha-rhombohedral form, the intermediate tetragonal type, and the high-temperature beta-rhombohedral polymorph. Additionally, amorphous boron and many complexes of the basic forms have been studied, including a new metastable tetragonal type. Several of the papers are concerned with the preparation and study of some of these forms of boron as well as with the production of single crystals for structure and property studies.

Metal borides are discussed in several papers, the family of five aluminum borides being the subject of a crystallographic study, while boron and the aluminum borides were studied from the standpoint of relating hardness to crystallographic faces and directions. Also, one paper describes five rare-earth and yttrium borides which belong to the UB_{12} cubic family of intermetallic compounds.

The properties of boron which receive most attention in this book are its electrical resistance, optical absorption, photoconductivity, infrared transmission, Hall constant, and hole density. Additionally, one presentation describes the high-temperature oxidation of boron, and another discusses its metallographic etching characteristics.

The major portion of the book is devoted to boron preparation, the evaluation of properties receiving far less attention. However, the contents give an adequate background on this not-so-simple material and should provide an excellent reference to those interested in boron or in hot-wire techniques, which are excellently described in several papers.

Pulp and Paper Manufacture, Bibliography, TAPPI

Edited by Jack Weiner; Technical Association of the Pulp and Paper Industry (1959); 718 pp.; $7.

Reviewed by S. F. Etris, ASTM Staff.

ANOTHER MASSIVE edition of the annual Bibliography and U. S. Patents of Pulp and Paper Manufacture, for the year of 1959, has been prepared by the Institute of Paper Chemistry for publication by TAPPI. Approximately 230 technical journals have been abstracted and some 2230 patents described covering areas of interest in the paper field from *Adhesives* to *Wood*.

(*Continued on page 416*)

CALENDAR

May 31–June 2—**The Engineering Institute of Canada,** Annual Meeting, Vancouver, B. C.

June 4–7—**National Association of Purchasing Agents,** Forty-sixth Annual International Convention and Inform-A-Show, Conrad Hilton Hotel, Chicago, Ill.

June 4–9—**American Waterworks Association,** Annual Conference, Detroit, Mich.

June 5–7—**Edison Electric Institute,** Annual Convention, Waldorf Astoria Hotel, New York, N. Y.

June 5–7—**American Society for Quality Control,** Annual Convention and Exhibition, Sheraton Hotel, Philadelphia, Pa.

June 5–9—**Society of the Plastics Industry,** 9th National Plastics Exposition and Conference, Coliseum and Commodore Hotel, New York, N. Y.

June 5–9—**Society of Automotive Engineers,** Summer Meeting, Chase-Park Plaza, St. Louis, Mo.

June 7–9—**National Electrical Manufacturers Association,** Western Conference, Hotel Biltmore, Los Angeles, Calif.

June 11–15—**American Society of Mechanical Engineers,** Summer Annual Meeting, Statler-Hilton, Los Angeles, Calif.

June 13–16—**Institute of the Aerospace Sciences and American Rocket Society,** Hotel Ambassador, Los Angeles, Calif.

June 18–22—**Forest Products Research Society,** 15th National Meeting, Kentucky Hotel, Louisville, Ky.

June 18–23—**American Institute of Electrical Engineers,** Summer General Meeting, Cornell University, Ithaca, N. Y.

June 18–23—**American Electroplaters' Society,** 48th Annual Convention, Statler-Hilton Hotel, Boston, Mass.

June 19–24—**American Association for the Advancement of Science,** Pacific Division Meeting, University of California, Davis, Calif.

June 25–28—**American Society of Agricultural Engineers,** National Meeting, Iowa State University, Ames, Iowa

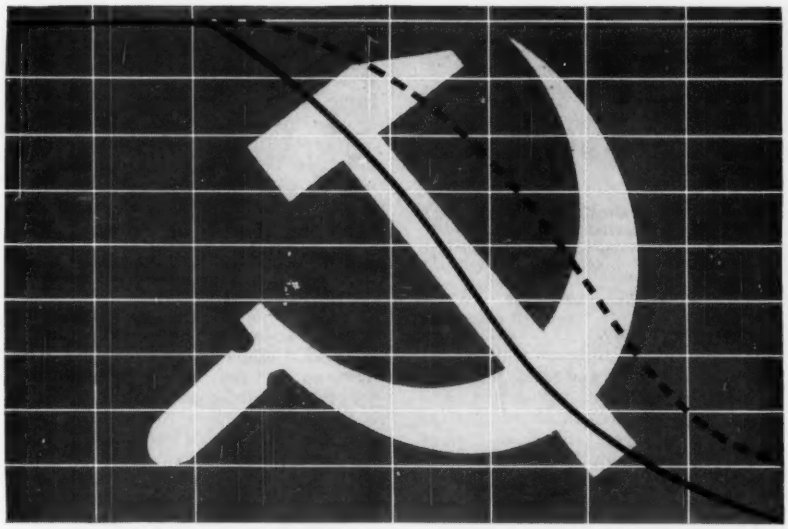
June 26–28—**American Society of Heating, Refrigerating and Air-Conditioning Engineers,** Annual Meeting, Hilton Hotel, Denver, Colo.

June 26–30—**American Society for Engineering Education,** Annual Meeting, University of Kentucky, Lexington, Ky.

June 28–30—**2nd Joint Automatic Control Conference,** Sponsored by ISA, AIChE, AIEE, ASME, and IRE. University of Colorado, Boulder, Colo.

July 5–8—**National Society of Professional Engineers,** Annual Meeting, Olympic Hotel, Seattle, Wash.

July 30–August 4—**American Crystallographic Association,** University of Colorado, Boulder, Colo.



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Automation and Remote Control

Avtomatika i Telemekhanika – Articles on all phases of automatic control theories and techniques. Published monthly by the Academy of Sciences, U.S.S.R. *('57, '58, '59 and '60 issues available)*

Measurement Techniques

(Izmeritel'naia Tekhnika)—Published monthly by Academy of Sciences, U.S.S.R. Particularly interesting to those engaged in study and application of fundamental measurement. *('58, '59 and '60 issues available)*

Instruments and Experimental Techniques

(Pribory i Tekhnika Eksperimenta)—Bi-monthly published by the Academy of Sciences, U.S.S.R. Articles relate to function, construction, application and operation of instruments in various fields of experimentation. *('58, '59 and '60 issues available)*

Industrial Laboratory

(Zavodskaya Laboratoriya)—Published monthly by the State Scientific-Technical Committee of the Council of Ministers, U.S.S.R. Presents articles on instrumentation for analytical chemistry and physical and mechanical methods of material research and testing. *('58, '59 and '60 issues available)*

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FOR FURTHER INFORMATION CIRCLE 1073 ON READER SERVICE CARD

(*Continued from page 414*)

Geologic Appraisal of Dimension-Stone Deposits

L. W. Currier, Geological Survey Bulletin 1109, (1960); 78 pp.; Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Reviewed by L. C. Gilbert, ASTM Staff.

THOSE INTERESTED in the appraisal of dimension-stone deposits as well as in acquiring a general knowledge in this area will derive great benefit from the wealth of information contained in this publication. The author, Louis Wade Currier, was associated with the U. S. Geological Survey for over 25 years until his retirement in 1960. His contributions have been many, not only through the USGS but through other avenues as well. One of these activities was his service as a member and chairman of ASTM Committee C-18 on Natural Building Stones. Through his efforts a number of ASTM standards on natural building stones have been developed and published by the Society.

The Bulletin presents a very complete story of the stone industry, commencing with an excellent introduction which orients the reader and particularly the field geologist in the background and purpose of the publication. The various uses of dimension stone are described, production statistics are given, and chemical and physical properties are reviewed in terms of their significance to a particular use. A prominent portion of the Bulletin is given over to the examination of deposits, which should be of inestimable value to the younger geologist in this field.

Reference is given in the last chapter to standard definitions of terms relating to natural building stones as published by ASTM under the designation C 119. The author was directly responsible for the development of these ASTM definitions. Further reference is given to the several ASTM standard methods of test for natural building stones developed by Committee C-18.

Federal Agencies Financing Research

Social Legislation Information Service, Inc., DuPont Circle Building, Washington 6, D. C. (1961); 26 pp.; $1.

Adapted from publisher's description.

IF YOU are interested in getting a research contract from any of the agencies of the Federal government, this publication should prove useful. Subtitled "The Complete 1961 Guide to Government Grants and Contracts," this booklet is designed to help persons or companies hoping to work on government research projects. It provides information on the programs, procedures, and organization of each agency awarding such contracts and names the officer to approach for further specifics. By following the suggestions contained in the booklet, interested groups are able to fit their qualifications and facilities to the needs of the appropriate departments. Also, browsing through the entire booklet may open new avenues not previously considered.

A subject cross-reference in the front of the book keys readers to proper agencies. For example, under "Cryogenics," readers are directed to listings that delineate research specifications of the Atomic Energy Commission, Department of the Army, and National Bureau of Standards. Other indexed headings range from agriculture to weapons systems, and include such varied fields as anthropology, business management, electronics, education, nuclear reactors, packing, toxicology, and space technology.

Congress has recognized the importance of both applied and pure research by authorizing more than $3 billion annually in federal funds. Of this total, more than half is spent for work performed outside the sponsoring agency by educational, industrial, and private concerns. The booklet should prove especially valuable to firms that have never been awarded government research contracts before.

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FOR FURTHER INFORMATION CIRCLE 1074 ON READER SERVICE CARD

Fundamental Principles of Powder Metallurgy

By W. D. Jones; St. Martin's Press, New York, N. Y. (1960); 1032 pp., Illus.; $30.

Reviewed by F. V. Lenel, Rensselaer Polytechnic Inst., Troy, N. Y.

THE APPEARANCE of W. D. Jones's book *Fundamental Principles of Powder Metallurgy* is an epochal event for powder metallurgists and important news for anybody interested in this field. Except for Goetzel's three-volume *Treatise on Powder Metallurgy*, most of which is over ten years old, there is no book on powder metallurgy as a whole available in print in English. The book fills a strongly felt need.

It will be remembered that Dr. Jones is the author of the first comprehensive English book on powder metallurgy, his *Principles of Powder Metallurgy*, published in 1937. This first book was distinguished by the author's attempt to go beyond pure description of the processes involved in the powder metallurgy technique and of the properties of its products, and to come to an understanding of the fundamental principles involved in these processes and properties.

The new book is much more than a new edition of the older one. It is, in

fact, an entirely new book, containing over 1000 pages compared with the relatively modest fewer than 200 in the first one. It has, however, preserved the distinguishing characteristic of the first one. Whether the author treats the production of powders by chemical reactions or by mechanical processing of the solid metals; the pressing of metal powders or the sintering of the resulting compacts; or the mechanical or magnetic properties of sintered products, their use as contacts, as bearings, or as friction materials, in every case he goes back to first principles. He discusses the history of his subject and then shows how our present understanding of the processes and properties can be based on first principles. Where such understanding is lacking, he points out what experimental or theoretical work should be done to supply it. In case after case he provides an excellent condensed treatment of the principles involved and is particularly generous with references to books or articles where extended discussion can be found.

For many years, Dr. Jones has been the co-editor of *Metal Powder Report*, a magazine devoted to abstracts of books, papers, reports, and patents in the powder metallurgy field. He therefore knows it probably better than anybody else living and has made use of this extensive knowledge in writing his book. Of particular value is his ability to draw on the literature in fields related to powder metallurgy, for example, in his discussion of the settling of powders.

As the title of the book indicates, Dr. Jones is primarily interested in principles. Commercial applications are discussed only in so far as they illustrate these principles. Under these circumstances it is to be expected that certain applications which are of particular interest to the author are discussed much more in detail than others in which he is less interested. In any case, in spite of the bulk of the book, it should not be considered an encyclopedia of powder metallurgy.

The first four chapters, which take up almost two thirds of the book, discuss the basic steps of the powder metallurgy technique, manufacture of powders, pressing, shaping without pressing, and sintering. Particularly noteworthy is the chapter on powder manufacture, in which Dr. Jones presents not only the principles, but also details of most of the commercially important powder-producing processes. In the fifth chapter, entitled "Attainment of Specific Qualities," the author discusses the effect of dispersions upon the mechanical properties of powder metallurgy products, magnetic materials made by powder metallurgy, including

(*Continued on page 418*)

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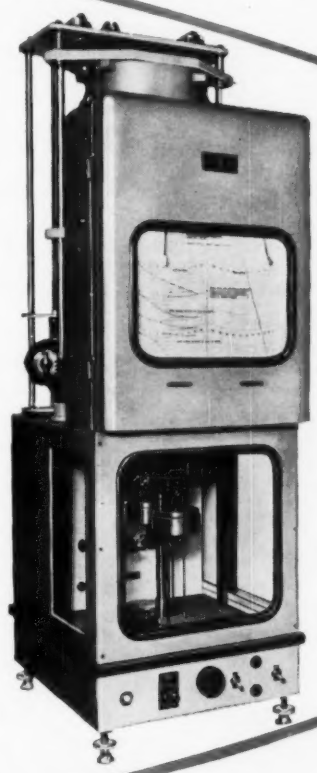

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(*Continued from page 417*)

"dust cores" and ferrites, porous materials, bearings, and friction materials. In the final section of the chapter he makes an attempt, perhaps not quite successful, to outline those factors which decide whether in any particular application powder metallurgy is competitive with other methods of fabricating machine parts. The sixth chapter, "Continuous Powder Metallurgy," outlines recently developed processes for producing sheet, strip, rod, tubing, or extrusions from metal powders. As Dr. Jones points out in his preface, "it may well be that they will amount to a substantial proportion of all metallurgical processes" in the years to come. They deserve the close attention of anybody concerned with metallurgical processes of the future. The book closes with a very brief 13-page outline of "Methods of Control" of powders and powder products.

The printing and the reproduction of figures in the book is very good. It has a name, a patent, and an exhaustive subject index. Its high price is, in this reviewer's opinion, well justified by what is offered in its pages.

NEWS OF MEMBERS

Stephen Brunauer, manager of Basic Research Section, Portland Cement Assn., Research and Development Laboratories, Skokie, Ill., received The Kendall Company Award in Colloid Chemistry at the recent meeting of the American Chemical Society.

E. Alfred Burrill, vice-president and director of marketing, High Voltage Engineering Corp., Burlington, Mass., delivered the Lester Honor Lecture at the Fifth Western States Convention of the Society for Nondestructive Testing in Los Angeles, Calif. The title of the lecture was "High-Energy Nuclear Radiations—Their Implications for Industry."

Robert Cass retired recently as assistant to the president, The White Motor Co., Cleveland, Ohio. He is now a lecturer at the University of Portland, Portland, Ore.

W. V. Cropper, formerly chief chemist, American Oil Co., Whiting, Ind., is now general manager, Precision Scientific Development Co., Chicago, Ill.

Lloyd A. Cummings, a member of the Board of Directors Marlin-Rockwell Corp., Jamestown, N. Y., retired recently, Mr. Cummings has been an ASTM member for 15 years.

Theodore A. Dumas is a mechanical engineer, Collins Radio Co., Richardson, Tex. Previously he was an engineer trainee, Hughes Tool Co., Houston, Tex.

Ivan G. Easton, vice-president for engineering, General Radio Co., West Concord, Mass., has been appointed to an advisory committee on calibration and measurement services recently established by the National Bureau of Standards. As a liaison between NBS and industry, the committee will serve to coordinate precision measurement, calibration, and standardization practices.

Walter B. Farnsworth, chief metallurgist, Pittsburgh Steel Co., Monessen, Pa., retired February 28, 1961. Mr. Farnsworth was a member of ASTM for 25 years.

O. B. J. Fraser, assistant manager, Development and Research Div., The International Nickel Co., Inc., New York, N. Y., retired recently. Mr. Fraser, a long-time member of the Society, represented his company on Committee B-2 on Non-Ferrous Metals and Alloys and the Joint Committee on Filler Metal. He will continue his Society membership and committee activities. Mr. Fraser has

(*Continued on page 420*)

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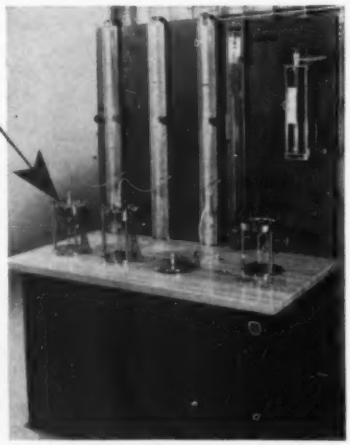
THE DOW GAS TRANSMISSION CELL

The cell was developed to measure the gas transmission rate of plastic sheeting and plastic coated papers. The unit is designed to have all parts removable for cleaning and replacing. The manometer system of the cell is calibrated, and adapters are furnished for fast and slow gas transmission rates. A typical three cell console is shown on the right.



Console

CSI PLASTICS TESTERS CHECK LIST

- ☐ ABRASION (ASTM D-1242) Armstrong Abrader
- ☐ ADHESION (ASTM D-Proposed) Climbing Drum Peel Apparatus
- ☐ COMPRESSION SET (ASTM D-395) Compression Set Apparatus
- ☐ ENVIRON. STRESS CRACKING (ASTM D-1693) Nicking Jig, Bending Clamp, Transfer Tool
- ☐ FLAMMABILITY (ASTM D-1433) SPI Flammability Tester
- ☐ GAS TRANSMISSION (ASTM D-1434) Dow Gas Transmission Cell
- ☐ HEAT DISTORTION (ASTM D-648) Heat Distortion Tester
- ☐ IGNITION (ASTM E-136) Setchkin Self-Ignition Apparatus
- ☐ COMPRESSION AND RECOVERY (ASTM D-1147) Armstrong Indentation Machine
- ☐ RESILIENCE Nopco Ball Rebound Tester
- ☐ THERMAL CONDUCTIVITY (ASTM C-177) Alundum Guarded Hot Plate
- ☐ TORSION (ASTM D-1043) Torsion Tester

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FOR FURTHER INFORMATION CIRCLE 1076 ON READER SERVICE CARD

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MICRO-TESTERS

FOR THE MECHANICAL AND MICROMECHANICAL INVESTIGATION OF MATERIALS AND FIBERS

MI-2 UNIVERSAL TESTING MACHINE WITH GRAPHIC RECORDING
TENSION · SHEAR · BENDING · COMPRESSION · HARDNESS AT AMBIENT AND ELEVATED TEMPERATURES.
MAXIMUM LOAD 5000 LBS.
(3 INTERCHANGEABLE DYNOMETER SPRINGS AVAILABLE.)

For medium size specimens, the MI-2 is exceptionally accurate and simple to operate. It graphically records load-deformation diagrams and results in added economy through the small-sized specimens required.

MI-3 MICROMACHINE WITH PHOTOGRAPHIC RECORDING
· TENSION · SHEAR · BENDING
MAXIMUM LOAD 700 LBS.
(4 INTERCHANGEABLE DYNAMOMETER SPRINGS AVAILABLE.)

A specially designed machine for the investigation of very small specimens, the MI-3 measures deflection through a dynamometer spring and records it photographically employing a flawless optical tripod system.
Electronically driven and controlled, the MI-3 allows derived curves giving data in the micro-crystalline orders of magnitude.

MI-4 MICROMACHINES WITH PHOTOGRAPHIC RECORDING
TENSION IN METALLIC WIRES AND STRIPS, TEXTILE FIBERS AND THREADS, FABRICS AND PAPERS, AT LOW, AMBIENT AND HIGH TEMPERATURES.
MAXIMUM LOADS: MI-44/I 500 GR., MI-44/II 150 LBS., MI-44/III 200 LBS.
(18 INTERCHANGEABLE DYNAMOMETER SPRINGS AVAILABLE)

In two sizes, the MI-44/1 and MI-44/2 photographically record stress-strain diagrams through a flawless optical tripod system. With two tripods, one direct mounted and the other differentially mounted, a wide test range is assured.
Silicone Steel dynamometer springs and electronically controlled motors make the MI-4 machines fast and accurate.

MI-5 MICROMACHINE WITH PHOTOGRAPHIC RECORDING
ALTERNATING TORSION-MAX COUPLE ± 0.05 kgm

To determine the fatigue limit of a specimen, for determination of internal friction from the energy dissipated per alternation, and to follow the progress of fatigue as a function of the number of alternations the MI-5 is an unexcelled performer.

MI-8 THERMOBALANCE

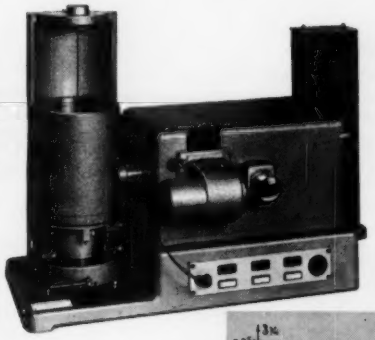
With mechanical or photographic recording, the applications are manifold. Designed to be insensitive to vibration and change in ambient temperature, it is especially useful for the most critical analysis of:

- Dry oxidation of metals and alloys
- Solid system changes accompanied by addition or loss of gas or vapor
- Dissociation of true chemical compounds formed when a gas is absorbed by a solid
- Thermal data on the calcination of precipitates
- Drying products in powder form

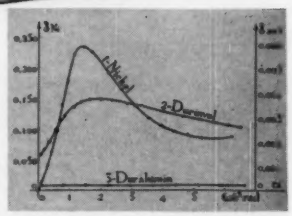
MI-9 MICROPENDULUM "COULOMB"

Specially designed for a specific field of testing, the MI-9, through attenuated oscillations, determines:

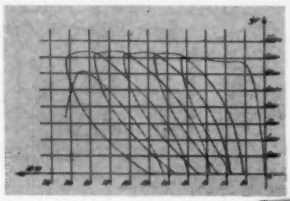
- The variations of internal friction in metals
- Magneto-elastic anomalities of metals and ferromagnetic alloys
- Changes of internal friction due to cold working
- The mechanical hysteresis and fatigue of metals.



MI-9

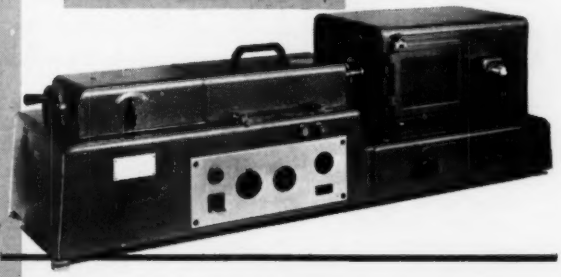


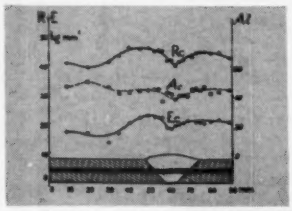
Curves plotted by evaluating the damping diagrams. On the Nickel and Durinval curves the magneto-elastic anomalities inherent to ferromagnetic materials is clearly defined.
The very slight decrement of Duralumin is so-to-say independent of the amplitude.



MI-44

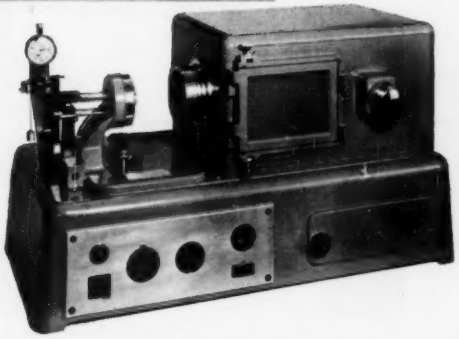
Load-deformation curves of flat, colorless extruded polyethelyne, employing a 3 kg. maximum capacity dynamometer.





MI-34

Detailed investigation of a weld made by carrying out Micro Shearing tests. A Chromium-Molybdenum steel welded with an electrode of the same material.



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NEWS OF MEMBERS

(*Continued from page 418*)

been actively identified as both officer and member of committees of many metallurgical and engineering organizations. He will maintain interest in many chemical and metallurgical activities and will engage in consultation in those fields.

Desmond A. George, previously a physicist, National Bureau of Standards, Washington, D. C., is now a chemist, Scientific Liaison and Advisory Group, U. S. Department of the Army, Washington, D. C.

William G. Gerry is assistant manager of civil engineering services (A/MCE), Department of National Defense, Navy, Esquimalt, B. C., Canada. Formerly he was manager, Terra Engineering Laboratories, Ltd., Victoria, B. C., Canada.

James W. Goff, associate professor, School of Packaging, Michigan State University, East Lansing, Mich., has been promoted to professor.

Joseph F. Greene retired February 28, 1961, from his position as manager of customer research for the Blown and Tube Div., Kimble Glass Co., (subsidiary of Owens-Illinois Glass Co.), Vineland, N. J. Mr. Greene joined the Society in 1937.

Waldemar C. Hansen, manager, Research Laboratories, Universal Atlas Cement Div., United States Steel Corp., Gary, Ind., retired February 28, 1961. Dr. Hansen will do consulting work and continue his membership in the Society and on Committees C-1 on Cement and C-9 on Concrete and Concrete Aggregates.

J. Harry Jackson, supervising metallurgist, Battelle Memorial Inst., Columbus Ohio, has assumed his duties as chairman of the Institute of Metals Division of The Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers.

Malcolm T. Johnson, formerly engineer, Electric Boat Div., General Dynamics Corp., Groton, Conn., is serving in the same capacity with International Steel Corp., Evansville, Ind.

W. G. Kirkland, chief engineer, American Iron and Steel Inst., New York, N. Y., has been elected assistant vice-president.

John W. Lendved, formerly director of engineering, Construction Machinery Div., Chain Belt Co., Milwaukee, Wis., is now manager, Rec. Hunnebeck GmbH., Düsseldorf, Germany. Mr. Lendved is assisting in the organization of this firm, which is partially owned by Chain Belt Co.

L. J. Markwardt, Madison, Wis., honorary member and past-president of ASTM, has been named vice-president of the International Wood Research Society.

Dexter H. Mead, manufacturing assistant to vice-president, Revere Copper and Brass Inc., Dallas Div., Chicago, Ill., retired recently. Mr. Mead's membership in the Society goes back to 1927, and for a number of years he participated in the work of Committee B-5 on Copper and Copper Alloys, Cast and Wrought.

Anthony Meola, manager, quality control, Monroe Calculating Machine Co., Orange, N. J., retired recently. Mr. Meola had been a member of the Society since 1957.

Frank W. Miller, contracting engineer, Lehigh Structural Steel Co., Allentown, Pa., retired January 1, 1961. Mr. Miller joined ASTM in 1956.

L. Mittelman, chief chemist, Tidewater Oil Co., Associated Div., Associated, Calif., retired recently. Mr. Mittelman joined the Society in 1927 and for many years was active on Committee D-2 on Petroleum Products and Lubricants.

Malcolm H. Nickerson is now vice-president and research director, Lexsuco, Inc., Solon, Ohio. He had been director of research, Construction Products Co., Suffolk, Va.

E. W. Pierce, chief metallurgist, United States Steel Corp., Chicago, Ill., retired December 1, 1960. Mr. Pierce was a member of the Society for 15 years.

Harold V. Rasmussen, a member of the Society since 1956, retired December

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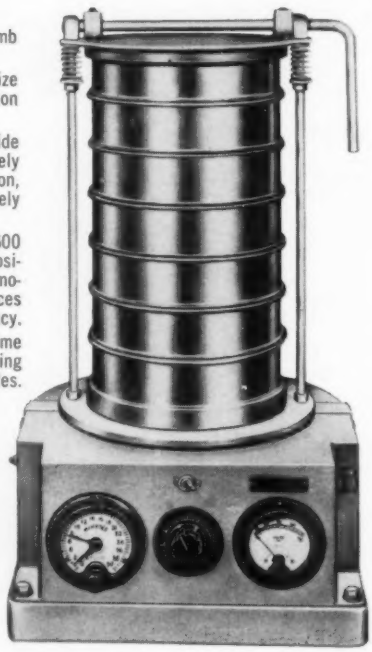
—will definitely establish the particle size required and set a standard for ideal production —provide permanent operational records.

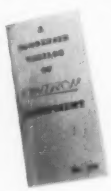
Syntron Vibrating Test Sieve Shakers provide these sieve analyses quickly and accurately contributing to a more profitable operation, insuring customer satisfaction, and a definitely uniform end product.

The electromagnetic drive unit produces 3600 vibrations per minute. It combines a sharp positive vertical movement with a slow rotating motion minimizing particle deterioration, induces faster separation, and insures high accuracy.

Equipped with a preset timer for accurate time test periods and a rheostat control for adjusting the voltage for uniform tests of all samples.

Easy to operate, easy to maintain.





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31, 1960, from Worthington Corp., Turbine Div., Wellsville, N. Y., as consulting engineer.

Stuart T. Ross, previously manager, physical metallurgy, Aeronutronic Div., Ford Motor Co., Newport Beach Calif., is now vice-president, research and engineering, Brooks & Perkins, Inc., Detroit, Mich.

William A. Sandberg, formerly structural engineer, South Pasadena, Calif., is now consultant, National Engineering Science Co., Pasadena, Calif.

Donald J. Schaefer has been appointed welding division manager, The Champion Rivet Co., Cleveland, Ohio.

Julian W. Shields, previously staff engineer, Union Carbide Metals Co., Division of Union Carbide Corp., Niagara Falls, N. Y., is now engineer, Union Carbide Chemicals Co., Division of Union Carbide Corp., South Charleston, W. Va.

Norman H. Spear has been appointed general manager, Roth Laboratory for Physical Research, Hartford, Conn. Formerly, he was general manager, blow molding, Olympic Plastics Co., Los Angeles, Calif.

Arthur U. Theuer is now president, Foundation Constructors, Inc., Waltham, Mass.

C. J. Tobin retired recently from General Motors Corp., Warren, Mich. For many years, Mr. Tobin was a member of Committees B-2 on Non-Ferrous Metals and Alloys and E-4 on Metallography.

A. L. Van Emden, retired, U. S. Department of the Navy, Bureau of Ships, Washington, D. C., was the guest of honor at a luncheon on February 15 given by Committee B-4 on Metallic Materials for Thermostats and for Electrical Resistance, Heating, and Contacts. At that time he was presented with an honorary membership in the committee in recognition of his outstanding contributions during his many years of active membership. Mr. Van Emden represented the Bureau of Ships on Committees B-4, D-10 on Packaging, D-13 on Textile Materials, D-20 on Plastics, and D-27 on Electrical Insulating Liquids and Gases.

Milton F. Wagnitz, city engineer, Department of City Public Works, City of Detroit, Mich., retired recently after 42 years. Mr. Wagnitz represented the department in Society membership.

Walfrid Warner, Mt. Prospect, Ill., retired recently. Mr. Warner joined the Society in 1947 and had been a member of Committee A-1 on Steel.

H. E. Wiedemann, consulting chemist, St. Louis, Mo., has retired from active work. His laboratory is being sent to his alma mater, Rose Polytechnic Inst. Mr. Wiedemann will continue his membership in the Society, which began in 1924.

H. M. Wilten, Texaco, Inc., Port Arthur, Tex., retired August 1, 1960. Mr.

(*Continued on page 422*)

HEVI-DUTY "Multiple Unit" TUBE TYPE COMBUSTION FURNACES

in Two Temperature Ranges, 1850° F. or 2200° F.

Hevi-Duty Combustion Tube Furnaces are available in either the split* (illustrated) or solid type and can be used horizontally or modified for vertical operation. Long-life "Multiple Unit" brand heating units offer fast heat-up because the heat is radiated directly into the heating chamber. The heated length may be divided for zone temperature control which gives greater temperature uniformity over a specified length. A few of the standard furnaces are shown below. Many sizes are in stock. Special sizes with diameters up to 16 inches can be built to your specifications.

*5-in. and smaller diameters are hinged.

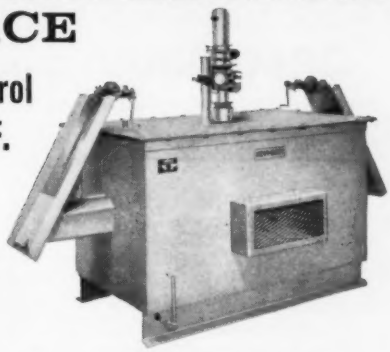
HINGED-TYPE TUBE FURNACE FOR 1850° F.					
TYPE	CHAMBER		RATING WATTS	SHIPPING WEIGHT	PRICE
	DIA.	LENGTH			
70	1¼"	12"	750	35	$ 75.00
M-2012	2⅜"	12"	1400	90	$ 165.00
M-3024	3"	24"	3400	135	$ 250.00
M-5036	5"	36"	7500	325	$ 650.00
M-8040	8"	40"	14500	520	$1180.00

Write for Bulletin 552 for complete details.

FOR GENERAL AND SPECIALIZED LABORATORY APPLICATIONS

HEVI-DUTY MOLYBDENUM TUBE FURNACE

For long life, accurate control at temperatures to 3,000° F.



Maximum Temperature Uniformity

Low thermal conductivity of insulation reduces heat losses and provides uniform temperatures in the heating chamber. Optional purge and water-jacketed chambers allow charge to be preheated and cooled in protective atmosphere.

Protection is Built In

Special reactor transformer control system guards against overloading the molybdenum heating elements — supplies minimum initial voltage to cold elements — increases voltage as heat and resistance increase.

Easy to Operate, Simple to Service

Furnace may have either an automatic indicating and controlling pyrometer or manual controls and optical sighting window. Either system will give accurate temperature control. Top of furnace is removable for easy access to elements.

HEVI-DUTY

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Get full details on this high-temperature laboratory furnace in Bulletin 758

HEVI-DUTY ELECTRIC COMPANY, WATERTOWN, WISCONSIN

Industrial Furnaces and Ovens, Electric and Fuel • Laboratory Furnaces • Dry Type Transformers • Constant Current Regulators

FOR FURTHER INFORMATION CIRCLE 1079 ON READER SERVICE CARD

NEWS OF MEMBERS

(*Continued from page 421*)

Wilton had served on Committees A-1 on Steel, A-5 on Corrosion of Iron and Steel, A-10 on Iron-Chromium, Iron-Chromium Nickel and Related Alloys, B-2 on Non-Ferrous Metals and Alloys, and the Petroleum and Chemical Panel of the Joint Committee on Effect of Temperature on the Properties of Metals.

Herbert A. Winkelmann, vice-president and technical director, Dryden Rubber Div., Sheller Manufacturing Corp., Chicago, Ill., received the 1961 Charles Goodyear Medal of the American Chemical Society, Rubber Div. He was honored as co-inventor of the first antioxidant for rubber to be marketed.

Ruby K. Worner, textile technologist, U. S. Department of Agriculture, Southern Utilization Research and Development Div., New Orleans, La., has been given a certificate of service by the American Association of Textile Chemists and Colorists. She is now lecturer and consultant at the University of Alexandria in Egypt on a Fulbright grant.

H. F. Yancey, supervising engineer, U. S. Bureau of Mines, University Campus, Seattle, Wash., retired December 31, 1960. Mr. Yancey had been a member of the Society since 1954 and served on Committee D-5 on Coal and Coke.

DEATHS

Clyde C. Conner, consultant on masonry construction and maintenance, Verona, N. J., retired assistant engineer, New Jersey Bell Telephone Co., Newark, N. J. (March 4, 1961). Mr. Conner, a member of the Society for 30 years, was active in Committee C-7 on Lime, C-12 on Mortar for Unit Masonry, and C-15 on Manufactured Masonry Units.

Edgar K. Mull, chief metallurgist, Industrial Forge and Steel, Inc., Canton, Ohio (November, 1960). Mr. Mull was an ASTM member for 20 years and served on Committee A-1 on Steel.

Sidney Rolle, consulting metallurgical engineer, Princeton, N. J. retired assistant manager, The Scomet Engineering Co., New York, N. Y. (March 25, 1961). Mr. Rolle was killed in an automobile accident while he and his wife were traveling in France. He was a member of the Society for 20 years, and his committee activities spanned a period of 26 years. He was active in Committee B-2 on Non-Ferrous Metals and Alloys, Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Committee B-1 on Wires for Electrical Conductors, and the Joint Committee on Classification of Coppers. Mrs. Rolle died April 4 from injuries suffered in the accident.

Ernest E. Thum, a member of the Society since 1924, and editor-in-chief, *Metal Progress*, American Society for Metals, Metals Park, Novelty, Ohio (April 11, 1961). Mr. Thum's technical committee activities also date back to 1924 and include Committees A-1 on Steel, B-2 on Non-ferrous Metals and Alloys, E-8 on Nomenclature and Definitions, E-4 on Metallography, E-5 on Fire Tests of Materials and Construction, B-6 on Die-Cast Metals and Alloys, B-9 on Metal Powders and Metal Powder Products, and E-1 on Methods of Testing as a representative of E-4. His main interest was in Committee B-2, which he served as secretary from 1928 to 1939, chairman from 1939 to 1948, and honorary vice-chairman from 1948 to the time of his death. Mr. Thum was the recipient of the ASTM Award of Merit in 1954.

Jack H. Waggoner, technical assistant to general manager, Pittsburgh Plate Glass Co., Fiber Glass Div., Pittsburgh, Pa. (February 21, 1961). Mr. Waggoner's ASTM membership and committee activities covered a period of almost 25 years. His committee activities included C-14 on Glass and Glass Products, C-16 on Thermal Insulating Materials, which committee elected him to honorary membership, and D-13 on Textile Materials.

Reliable, Consistent Test Results With . . .

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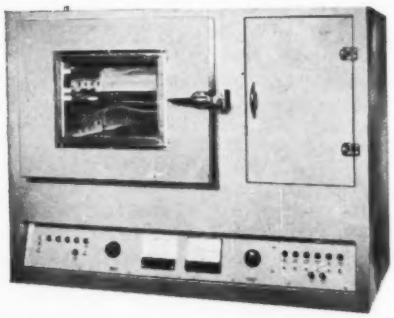
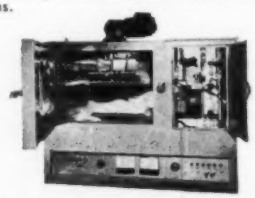


Orec 0300 Series employ an *electronic-chemical loop feed back servo system to achieve and precisely maintain chamber ozone concentrations.



Orec 0300 with Dynamic Stretching Apparatus.
* patent pending

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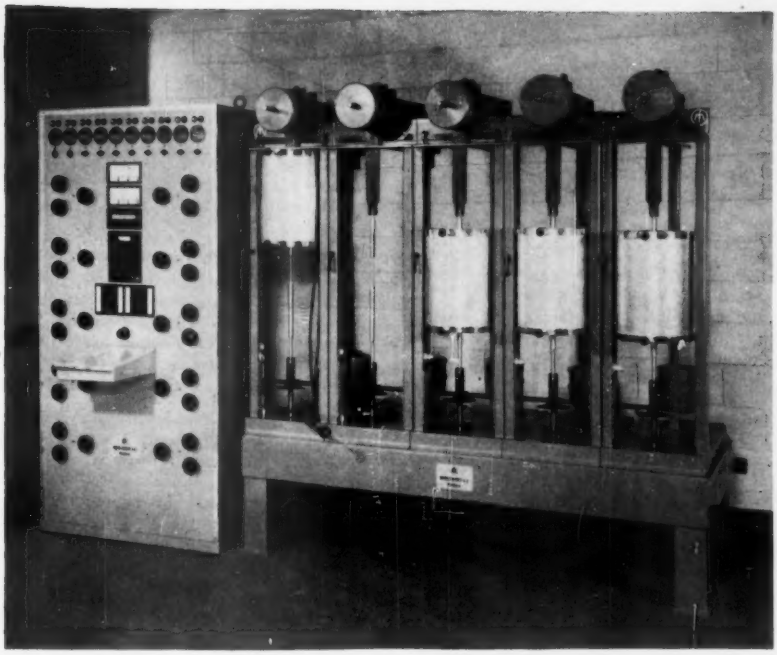
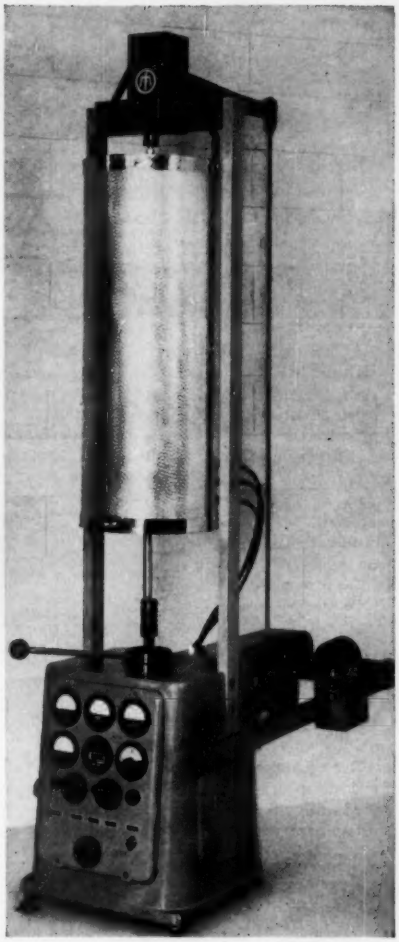


Above: The control cabinet shown has regulating and measuring equipment suitable for 10 furnaces. The furnaces are independent from one another. Equipment of this type is desirable for research and original explorations.

MOHR & FEDERHAFF

Creep Strain Testers

SINGLE SAMPLE OR MULTIPLE SAMPLE



Ten samples strung end to end are accommodated by this tester. Its low cost per specimen makes large volume routine testing possible.

Creep testing has in many instances progressed from an experimental to a routine basis in the past few years. The physical properties of a steel which is to be used at normal temperatures can be determined by a simple test, because the properties of steels do not change with time at ordinary temperatures. However, the designers now want materials which will endure high temperatures under load for long time periods. Such materials are needed to obtain greater efficiency in modern and future engines, turbines and other machinery. We have the problem of testing many possible materials at many possible loads at many different temperatures over many different time periods. The question arises—Is it possible to test for a short period, say 48 hours and extrapolate the results for longer times? Unfortunately, in most cases the answer is no, if temperatures over about 400° C. (720° F.) are under consideration. Test periods of 1,000 to 10,000 hours are common and tests up to 100,000 hours (over 10 years) are being carried out.

It is obvious that a large number of single sample testers would be required for a long term test program on even a few steels.

Mohr & Federhaff, in cooperation with some of the most advanced creep test laboratories in Europe, have arrived at the following solution: A few individual or battery type testers for individual samples should be used for research and experimental work with the balance of the long term testing being handled by multiple testers accommodating 10 samples fastened end to end in one furnace and loading system. This has made large scale testing possible.

We believe an examination of the problem indicates that the combination of a few single unit creep testers with several multiple testers affords the most satisfactory means of obtaining voluminous creep data.

A COMPLETE LINE OF TESTING MACHINES FOR TENSION, COMPRESSION, BENDING, CUPPING, HARDNESS, CREEP, TORSION, DROP, CALIBRATION, MEASURING AND SPECIAL PURPOSE TESTS.

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MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Pressure Calibrator—The Armcorp portable differential pressure tester and calibrator provides a means of checking gages, flowmeters, transducers, regulating units, and other equipments that operate on differential-pressure principles. It incorporates its own pressure sources for applying accurately measured pressures in discrete increments. It permits checking installed equipment from remote position without compromising the accuracy of the test.

American Research and Manufacturing Corp. **3729**

Scan Accessory—A new repetitive scan accessory for operation with Cary spectrophotometers is announced. This accessory permits the spectrophotometer to operate unattended over a preselected wavelength span. It is especially useful for kinetic or other time-base studies or for scanning a series of similar samples.

Applied Physics Corp. **3730**

Spectrograph—A complete quantometer laboratory for less than $22,000 is announced. The development of a new line of modular source units and the Model 29000 direct-reading spectrometer is said to permit maximum economy in spectrochemical analysis. The spectrometer, along with a spark source and recording console, is a production control quantometer. The laboratory installation provides accurate, precise, and rapid chemical analyses of nearly every material use in industry.

Applied Research Laboratories, Inc. **3731**

Strain Gage—A new bonded resistance-foil strain gage with a built-in computer that solves general strain-to-stress equations automatically has been developed. The new gage will simplify the task of obtaining stress readings in a wide range of testing and measuring applications by automatically eliminating the need for tedious, time-consuming calculations of stresses from the strain indications.

Baldwin-Lima-Hamilton Corp. **3732**

Infrared—Marketing of a new IR-5A infrared spectrophotometer has been announced. The automatic recording instrument now features both single- and double - beam operation. Wavelength range is 2 to 16 μ with a wavelength accuracy of ± 0.030 μ. Stray light is less than 4 per cent at 14.3 μ.

Beckman Scientific and Process Instruments Div. **3733**

Glass Lathe—A glass lathe of small dimensions but having a capacity sufficient for the wide range of requirements to suit the needs of the professional glass-blower as well as the chemist or physicist has been developed.

Bethlehem Apparatus Co., Inc. **3734**

Angle-Beam Transducers—An entirely new group of angle-beam transducers for use with ultrasonic flaw-detection equipment has been announced. Designed primarily for flaw detectors, the transducers may also be used successfully with similar ultrasonic instruments.

Branson Instruments, Inc. **3735**

Balance—A new, higher capacity Electrobalance® is announced for general use in spectroscopy and other forms of instrumental analysis. It is said to be excellent for specific analytical methods involving samples up to 1 g, and most methods in microchemistry. It significantly extends the capabilities of the general chemical laboratory, supplementing the chemical analytical balance at the low end of its range.

Cahn Instrument Co. **3736**

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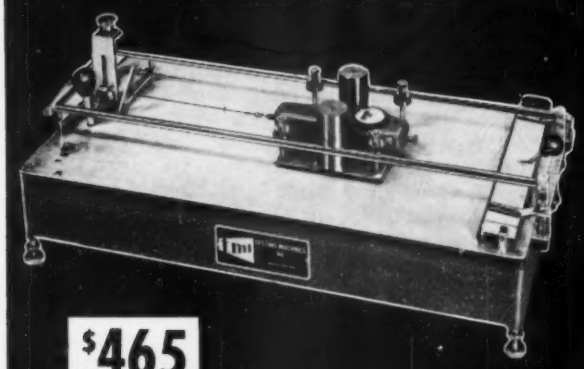

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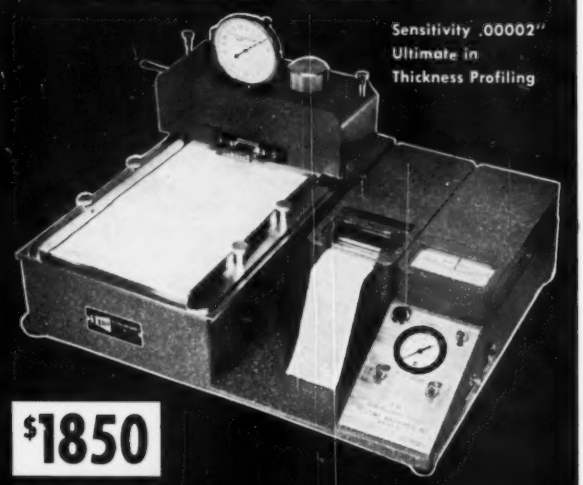

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The Finest Test Equipment for ALL Industries

FOR FURTHER INFORMATION CIRCLE 1082 ON READER SERVICE CARD

Environmental Chamber—New 0.5 cu ft environmental chamber is useful for R&D testing, moderate job shop applications, expansion fit assembly, as well as medical research and pharmaceutical or biological storage.
Cincinnati Sub Zero Products **3737**

Voltmeter—A new d-c voltage standard and null voltmeter has been developed. The new unit, the KIN TEL 302, is an accurate and compact source of variable-voltage low-impedance direct current. Standard cell stability on the 302 is obtained through the use of KIN TEL's chopper circuit which constantly compares the output against an internal mercury-cadmium standard cell.
Cohu Electronics, Inc. **3738**

Titrator—A new automatic laboratory titrator has been introduced for chemical analysis. Named the Coleman Titrion this titrator quickly, precisely, and automatically performs any titration in which the end point can be related to a reproducible electrode potential, including pH, redox, and conductometric procedures.
Coleman Instruments, Inc. **3739**

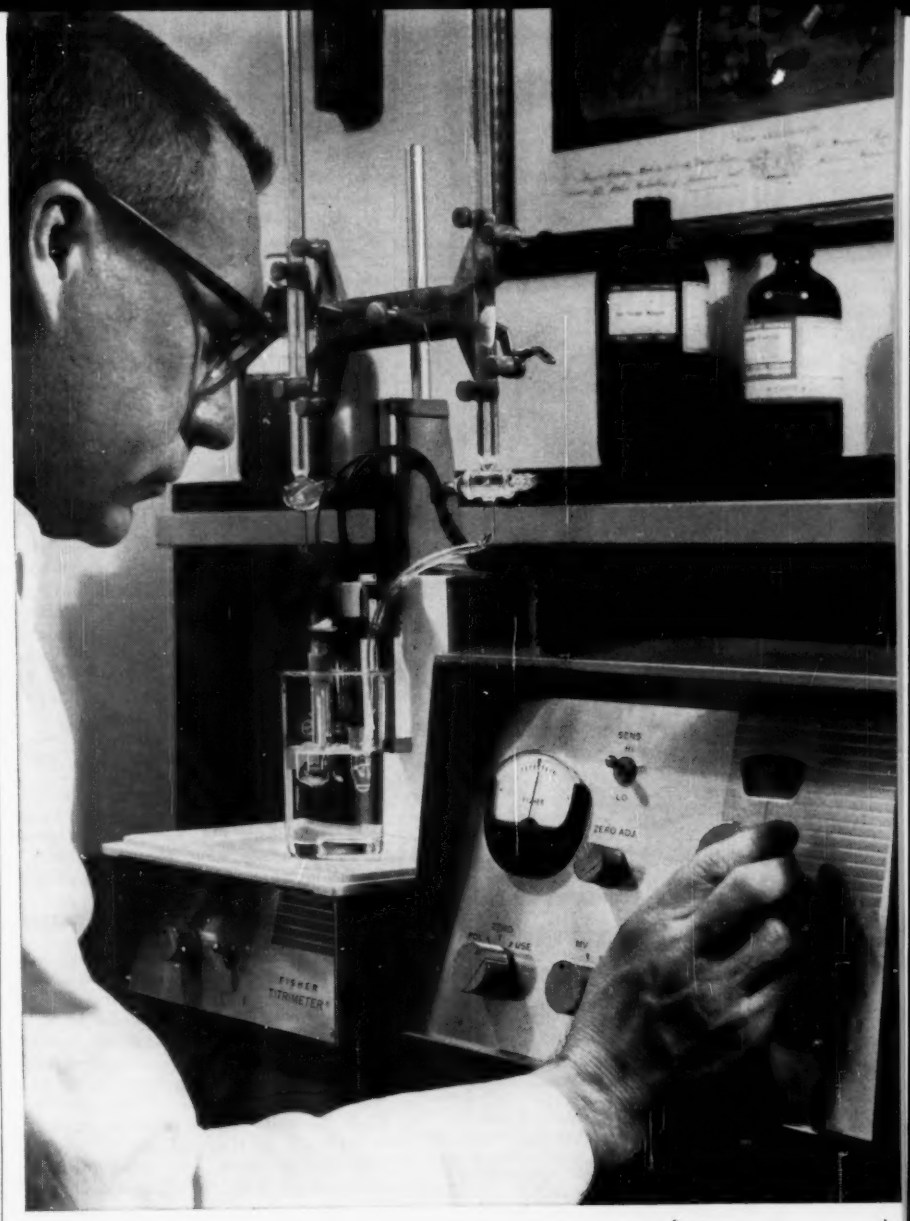
Tape Recorder—A new, versatile wide-band magnetic tape recorder-reproducer system designed for use in laboratory, ship, mobile van, or blockhouse environments has been developed. The VR-2600 recorder-reproducer features frequency response to 500 kc on direct record, 40 kc on FM, and 1000 bits per in. parallel recording with PCM techniques; six electrically selectable operating speeds from $1\frac{7}{8}$ to 120 in per sec in two ranges; all solid-state plug-in modular electronics; and all-metal front surface wide-band record and reproduce heads.
Consolidated Electrodynamics Corp. **3740**

LW Tester—Extra large sections of materials can be easily positioned and tested in this new Model LW extra wide tester. Standard width between the uprights has been increased approximately 80 per cent, from $8\frac{3}{4}$ to $14\frac{1}{4}$ in. In addition to this wide work area, four daylight openings are available (12, 20, 30, and 40 in.) to permit fixture travel in excess of the greatest anticipated elongation.
W. C. Dillon & Co., Inc. **3741**

Force Gage—The new Model 2106 force gage incorporates three force transducers in the same plane which accurately simulate point force loading. High sensitivity of 7 peak mv per peak lb is obtained plus the convenience of a center mounting hole. A stable design is provided because height is small compared to the diameter. This "flat" configuration removes concern about shear loads.
Endevco Corp. **3742**

Explosive Tester—A family of portable instruments for safe testing of explosives and other heat-sensitive devices has been developed. The Model IRB-111 impulse resistance bridge, a small, hand-held, self-powered unit is said to be the first of its kind. Described by the manufac-

(*Continued on page 426*)



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CompuDyne's DYNATEST* machine loads 50,000 pounds at 20 cps and can follow a programmed heating rate of 200°F/sec. to 3000°F simultaneously

Now you can get dynamic response characteristics well beyond the capabilities of conventional test machines by using DYNATEST Model DTM-3. The new machine meets demands created by rapid technological developments in nuclear, aeronautical, space vehicle and propulsion fields.

The Dynatest machine features a high-speed DYNAJACK* electrohydraulic ram arranged to program force and strain applied to the specimen. Continuous cyclical force or strain versus time may be employed with manual or full automatic programming. Temperature programming is accomplished by close coupled resistance heating or combinations of resistive inductive or radiant heating. Temperature is detected with a low mass thermocouple welded to the specimen.

Special environmental testing is greatly simplified because the Dynajack hydraulic load cylinder, load cell, and extensometer are easy to remove and can be placed in special jigs if necessary.

Complete specifications and details are in Data Sheet S-101. Write for your copy today.

*Tradename

CompuDyne Corporation

400 South Warminster Road

Hatboro, Pennsylvania

CIRCLE 1084 ON READER SERVICE CARD

FOR THE LABORATORY

(*Continued from page 425*)

turer as a major advance in concept over existing testing devices, the lightweight, highly reliable tester is designed to test propellant or cartridge-actuated devices in missile launch, separation, or destruct packages.

Fleming Industries, Inc. **3743**

Concrete Tester—A new addition to the wide line of concrete testing machines is the Model FT-10 "Jobsiter," a portable-type machine for testing cylinders, blocks, bricks, cubes, and beams. Of all-welded construction, and with a 250,000 lb load rating, it is said to be priced lower than previous models.

Forney's, Inc. **3744**

High-Voltage Test Sets—A new expanded line of compact high-voltage test sets is announced. Number of ratings in a-c sets are increased, and a standard line of d-c sets is now available. Standard a-c and d-c units are available from stock, while sets with optional features can be shipped in one fourth the time compared to previous units. The sets are said to conform to ASTM Specification D 149-59.

General Electric Co. **3745**

Screen—New accessories and equipment for use with the Gilson porta-screen have been announced. A new feature now available is provision for a "scalping" operation, when separation of test samples into more than six segments is required.

Gilson Screen Co. **3746**

Accelerometers—A new triaxial, biaxial, unidirectional line of servo accelerometers has been announced. Suitable for upper-air weather rocket applications as well as an aid for inertial guidance, surveying, construction, installing precision equipment, balance detection and calibration, these servo accelerometers are said to solve the axial lineup problem formerly encountered in the field and to provide substantial space savings. They are packaged complete with electronics, requiring only one mounting surface; internal axes are properly oriented in relationship to each other within 1 min of arc.

Gulton Industries, Inc. **3747**

Voltmeter—A new integrating digital voltmeter designed to provide more accurate measurements and greater versatility in digital data handling systems is now available. The new voltmeter, Model DY-2401, is said to provide a unique measuring advantage by reading the average value of voltage applied over a definite, selected sample period.

Hewlett-Packard Co. **3748**

Freezer—A series of freezers, Cryostor, that can provide for temperature ranges as low as −200 F, are now available. Featuring an adjustable temperature range control, the freezers are said to be ideally suited for laboratories. A 1½ cu ft capacity is available, although other sizes can be customized on request.

Instrumentation Associates **3749**

Pipets—The development of a new, improved case for all straight pipets has been announced. All current manufactured pipets are being shipped in the new cell pack cartons which feature a "honeycomb" cell-like interior of chipboard in a corrugated outer shell. The new standard case holds 18 pipets in three rows of six each. Formerly, pipets were individually wrapped, sealed on each end of the wrapper, and packed within a corrugated case.

Kimble Glass Co. **3750**

Charge Amplifier—An electrostatic charge amplifier, Model 565, for use with piezoelectric accelerometers has been introduced. The compact, stable, line-powered instrument converts the electrostatic charge signal from a natural quartz crystal transducer to a voltage signal compatible with the input requirements of oscilloscopes, recorders, and telemetering equipment.

Kistler Instrument Corp. **3751**

Readout—A small, lightweight, high-speed, in-line digital readout presently in use in military systems is now offered. Total panel space required for the deci-line reader is 0.65 in. height and 0.50 in. from the center of one digit to center of adjacent digit. Assemblies with three, four, five, and six digits are available immediately.

Litton Systems, Inc. **3752**

Furnace—Recently announced Model LP-2472H Dyna-Trol electric furnace is said to have a diversity of applications in many industries. Its wide range of temperatures makes it applicable for heat-treating, drawing, glass annealing, etc. With fans removed, temperature can be controlled from 300 to 2300 F; with forced convection fan, 150 to 1875 F temperatures can be accurately controlled.

L and L Manufacturing Co. **3753**

Ovens—To meet the growing demand for more safe processing ovens in hazardous atmospheres, also where safety from destruction by overheating of the processed material is of utmost importance, "Modernlab" has designed a new safety control system, said to be unique with this type of equipment. By using the "Modernlab" patented (2718573) automatic duplex heat control it is possible to automatically protect the processed materials from heat destruction in the event of failure of the master control.

Modern Laboratory Equipment Co., Inc. **3754**

Pipet Jars—Design and fabrication changes have been incorporated in the new line of pipet jars recently offered. The new Nalgene pipet jars are now blow-molded in one piece from polyethylene to provide a solid, leakproof receptacle with a minimum of locked-in stress.

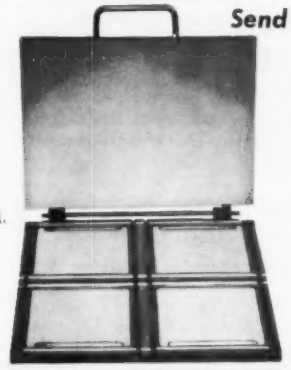
The Nalge Co., Inc. **3755**

Fluid Monitoring—A new model fluid monitoring system that offers more configurations in detecting and measuring the radioactivity in gas or water is announced. The system is designed to monitor stack gases, cooling loops, and effluent fluid lines discharging to sewer

(*Continued on page 428*)

✓ CHECK HOGGSON
PRODUCTION TOOLS and DIES *YOU* NEED and

Send for Information



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- ☐ 11. PORCUPINE
- ☐ 12. FLAT FACE
- ☐ 13. BEVEL
- ☐ 14. CONCAVE
- ☐ 15. KNURLED BEVEL FACE
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- ☐ 19. ASTM D575 CIRCLE CUTTER

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NEW Dillon REMOTE READING LOAD CELL SYSTEM

READS DIRECTLY IN POUNDS NO CIRCUIT BALANCING. NO CHARTS. CHOICE OF TENSILE COMPRESSION OR PUSH-PULL.

Designed upon differential transformer principle. Has no internal gears, levers or linkage to bind or wear.

Dillon Load Cells are accurate to within ½ of 1% of full capacity at any point on dial. Non-magnetic. Sensitive to load change of 1/10th of 1% of scale capacity. Tare loads up to 30% can be quickly canceled. Linear dial spacing made possible due to fact that output from Load Cell is in exact linear relation to mechanical displacement.

12 volt DC battery operated model or straight AC model optional. As many as four Load Cells may be used with one indicator which totalizes individual loads. Minute elongation of Load Cell, even when operating at peak, varies between .002" and .004" depending upon capacity.

Load Cells are fully sealed. Most capacities are of beryllium copper. Can't rust or corrode. Explosion-proof versions can be supplied on order. AN type sockets and plugs used throughout with heavy duty cable.

Temperature compensated circuit utilizes semi-conductors entirely. No tubes. No complicated, troublesome amplifiers. Load Cell safety factor is 4-1. Hysteresis is less than 1/10th of 1% of full scale capacity. Recorder jack is standard.

27 DIFFERENT CAPACITIES from as low as 0-150 pounds up to as high as 0-200,000 pounds. Variety of connectors such as swivel hooks, cable sockets, threaded studs, etc., available as accessories.

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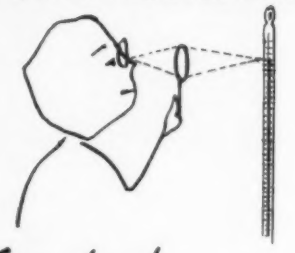
Once Upon a Time there was a Thermometer Watcher



Now he has a

THERM-O-WATCH

watching controlling and warning!

So he is free....

to..read journals write reports and think !!!

Saves Time, Saves $ $ $

CIRCLE 1087 ON READER SERVICE CARD

FOR THE LABORATORY

(*Continued from page 426*)

or hold-up tanks It consists of a Model FMS-1 mobile sampling tank and Model LCRM-22 logarithmic-count ratemeter.
Nuclear Measurements Corp. **3756**

Testing Machine—Third-point transverse tests are made quickly and easily on specimens with spans up to 15 ft long with the new Electromatic testing machine. Built-in arms extending to the front and rear of the machine have tee-slots that permit rapid adjustment of the self-aligning specimen supports to any standard span up to 15 ft. Load is applied from above the specimen by two hardened loading edges, which can be easily positioned as required to divide the span into three equal segments.
Tinius Olsen Testing Machine Co. **3757**

Dielectric Test—Designed to simultaneously test 10 reels of wire or cable in production plants, this new Model K3-4Y speeds up production testing, automatically disconnects faulty specimen, and permits balance to remain on test. It features independent fault indicator for each channel, optional timer for timed tests, zero-start high voltage on hold push button, safety door interlock and external interlock, plus other usual convenience and safety features including a 3-conductor safety grounding cord and plug.
Peschel Electronics, Inc. **3758**

Diffractometer—A new, high-temperature high-vacuum attachment for use with Norelco diffractometer installations is available. The precision high-temperature (ambient to approximately 1700 C) attachment consists of two major parts: water-cooled jacket with cover, and base plate with furnace stand and platinum specimen mount.
Philips Electronic Instruments **3759**

X-Ray Paper—An industrial X-ray paper that costs about half as much as standard X-ray film has been introduced. The paper, called "CAWO," produces 4 to 6 per cent sensitivity and is said to be excellent for finding flaws in sharp-contrast items such as electronic assemblies, tires, and metal-to-metal bondings.
Picker X-Ray Corp. **3760**

Shaker Baths—Any test requiring precisely controlled temperature as well as controlled agitation can now be made with 100 per cent repeatability, according to the manufacturer, thanks to a new line of stainless steel shaker baths. Bath temperature range is from ambient to 100 C with a guaranteed uniformity of ±0.5 C or better. The governor-controller shaker mechanism, unaffected by line voltage fluctuation, permits instantly variable speed settings of from 40 to 200 oscillations per min.
Precision Scientific Co. **3761**

Potentiometer—The "Quick Check" is a compact portable potentiometer designed to give the accuracy and ruggedness required in a hand-held testing instrument. With the "Quick Check" the problems of battery balancing, thermocouple polarity, ambient temperatures, and conversion charts are eliminated.
Pyrometer Service Co., Inc. **3762**

Gaussmeters—This instrument uses "classical" principles. A motor-driven rotating coil is the sensing element. When placed in a magnetic field, the coil acts as a simple a-c generator and the voltage output is a true measure of the field, without the nonlinearities.
Rawson Electrical Instrument Co. **3763**

Water Bath—An improved laboratory water bath shaker is announced. For *in vitro* reactions needing close control of temperature and regulated shaking, the apparatus provides temperatures from ambient to 90 C within ±0.5 C and also a wide selection of shaking conditions. Shaking speeds are continuously variable between 50 and 200 cpm, and the shaking stroke may be set at ½, 1, or 1½ in.
Research Specialties Co. **3764**

Hardness Tester—For testing the hardness of plutonium, this Vickers testing machine has been designed for glove-box operation. It is equipped with operating controls, 1800 F electric furnace, indexing compound, and microscope.
Riehle Testing Machines **3765**

Rotary Accelerator—Development of a centrifuge featuring solid coin gold slip rings for power and signal connections is announced. The unusual rotary accelerator has been designed to provide for the finest in laboratory instrumentation pick-up service.
Schaevitz Engineering **3766**

Penetrometer—A new pocket-style concrete mortar penetrometer for field and laboratory evaluation of the "initial set" of concrete has been developed. The penetrometer, which is only 7 in. long, can be used in conjunction with ASTM Method C – 403.
Soiltest, Inc. **3767**

Pressure Transducer—An extremely versatile, general - purpose unbonded strain gage pressure transducer, the P707TC, has been introduced. Available for measurement of absolute and gage pressures from 0 to 5 psi through 0 to 5000 psi, the new P707TC has been designed to withstand the stringent environmental conditions encountered in high-performance aircraft, space probes, and ballistic missiles.
Statham Instruments, Inc. **3768**

Temperature Guider—Temperatures in the range from 2000 to 2500 F can now be determined by Tempilstiks calibrated for 50 F intervals instead of every 100 F. These newly developed items bring to 86 the total number of available Tempilstik temperature ratings covering the range from 100 to 2500 F in systematic steps.
Tempil Corp. **3769**

Tearing Tester—The new air-operated grips are said to enable an operator to test twice as many specimens in less time with greatly reduced operator fatigue. Specimens can be inserted and removed

(*Continued on page 430*)

THWING-ALBERT ELECTRONIC TENSILE TESTER

An instrument for your present and future testing needs. Backed by over half a century of leadership and know-how in physical testing instrumentation.

Check these features:

Full scale ranges from 2 grams to 30,000 pounds
Sentronic "X-Y" Strip Chart Recorder
Infinitely adjustable pulling speeds
Adjustable chart magnification system up to 1000 to 1

Load and Extension Cycling
Simplified operating procedure
Grips and fixtures for every test—over 60 kinds
Electro-Hydraulic Pulling System

Thwing-Albert builds each instrument to your requirements. Many features can be added in the field. Your Tensile Tester can grow with your needs.

Write for more information; Send us samples of you material and learn how this versatile instrument can solve your testing problems.

THWING-ALBERT INSTRUMENT COMPANY

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Oxygen Bomb Apparatus

For rapid combustions in an oxygen bomb preparatory to determining sulfur, halogens, arsenic and other elements in solid or liquid samples.

The PARR 1901 apparatus shown above includes a 360 ml. self-sealing bomb with water bath, ignition unit and all accessories for combustion tests. Similiar outfits can be furnished with any of *seven* other PARR oxygen bombs.

Ask for Specification 1900

PARR INSTRUMENT COMPANY

211 Fifty-Third St. **Moline, Illinois**

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NEW!

PULL TESTERS

Accurate... fast... compact... low-cost... portable. Hunter's new Pull Tester offers all these advantages. Air-operated, this tester is made in 6 ranges up to 500 lbs. Write for Bulletin 750e.

HUNTER SPRING COMPANY
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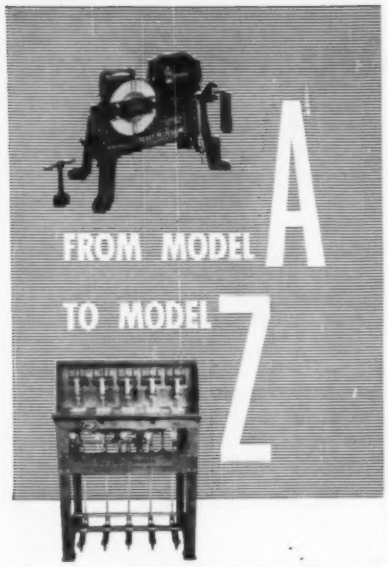
CIRCLE 1090 ON READER SERVICE CARD



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Whether you own a Scott tensile tester, a Scott Mooney Viscometer, or *any* other Scott Tester equipment . . . you can now get *certified* maintenance at very reasonable cost *anywhere* in the continental U. S. and Canada. Take advantage of the latest factory know-how and techniques to keep your testing equipment working properly and economically. Scott field men offer complete A to Z service, including:

• Inspection • Adjustment • Calibration • Minor Repairs • Work Report • Certificate of Calibration (often required on Government contracts)

Select either of two Scott Tester service plans:

(1) "GROUP SERVICE" PLAN
Regularly scheduled service trips are made from Spartanburg, S. C. and Providence, R. I. on a fixed fee basis.

(2) INDIVIDUAL SERVICE PLAN
For immediate service, or when service is required other than during scheduled group trips. Special rates quoted upon request.

(NOTE: Models CRE, ACCR-O-METER, STI and RMA are serviced only on special order.)

Write or call for complete information. Scott Testers, Inc., 120 Blackstone St., Providence, R. I.

SCOTT TESTERS

THE SURE TEST . . . SCOTT!

CIRCLE 1091 ON READER SERVICE CARD

FOR THE LABORATORY

(*Continued from page 428*)

in one easy operation without turning any screws. Air-operated grips using air pressures as low as 15 psi ensure uniform clamping pressure on the specimen at all times.
Thwing-Albert Instrument Co. **3770**

Ovens—Two new improved model lines in the forced convection series of ovens have now been introduced to provide closely controlled heat for processes with operating ranges to 1200 F.
Trent, Inc. **3771**

Environmental Chamber—A new walk-in style environmental chamber with a capacity of 2100 cu ft for electronic and other applications is offered. Known as Model WF-2100-125+300H, it provides a temperature range from +300 to −125 F, and a relative humidity range from 20 to 95 per cent. Inside unobstructed usable space is 15 ft wide by 20 ft deep by 7 ft high.
Webber Manufacturing Co., Inc. **3772**

NEW LITERATURE

Color Measurement—Literature describing the new Green-Bartlett technique of high-speed fully-automatic color measurement is now available. Designed to provide precise color signatures at rates as high as 30 samples per second, the equipment is well suited to feedback process control, continuous color inspection, and high-speed color sorting and grading. Information on this equipment, which has already been applied to industrial production color sorting, is provided in two 4-page brochures, one on general product sorting capabilities and the other describing technical details and applications of the colorimeter.
Allied Research Associates, Inc. **6420**

Ceramics—A property chart showing the mechanical and electrical properties of ceramics is available.
American Lava Corp. **6421**

Ovens—A new 12-page *Bulletin No. 1960* illustrates and describes the new line of mechanical convection ovens, such as laboratory production ovens, aging ovens, miniature batch ovens, hazard-safe ovens, five-drawer ovens, and testonic environmental cabinets.
Blue M Electric Co. **6422**

Metal Digest—Emphasis in Vol. VII, No. 1 is placed on introducing the new 1900 automet polisher attachment for grinding, rough polish, or final polishing. Complete illustrations, descriptions, and prices are included.
Buehler, Ltd. **6423**

Piezoelectricity—A 16-page illustrated booklet on the application of piezoelectric devices highlights new developments in high-power handling abilities of the materials. The booklet, designed to show the principal existing and potential uses of piezoelectricity, outlines and compares the performance characteristics of all major piezoelectric substances. Text and tables cover piezoelectricity as applied to convert mechanical energy to electrical energy and the reverse.
Clevite Electronic Components **6424**

Strain Gage—Description and design features of newest addition to the strain gage accelerometer family, the Type 4-203, are available in a two-page *Bulletin No. 4203*.
Consolidated Electrodynamics Corp. **6425**

Cryogenic Instrumentation—An illustrated data file describing activities in the field of cryogenic instrumentation is now available. *Folder CG 112R* contains information on equipment to measure accurately such parameters as temperature, pressure, flow, and liquid level for use in cryogenic environments.
Cryogenics, Inc. **6426**

Pressure Transducer—*Biography of a Very Versatile Pressure Transducer*, a four-page illustrated brochure describing the TP-200 line of pressure transducers is now available. The brochure contains performance data of six different versions of the TP-200 pressure transducer which can be used for measuring absolute, gage, or differential pressures of corrosive or noncorrosive gases or liquids with static of dynamic inputs in the ranges of 0 to 5 and 0 to 500 psi full-scale.
Fairchild Controls Corp. **6427**

Optical System—The new *Bulletin PL-1* contains complete details on the pinpoint lens holder available for both the miniature light source and miniature photocell housing. Describes applications, range, and ordering information.
Farmer Electric Products Co., Inc. **6428**

Catalog—New items of laboratory equipment are described, illustrated, and priced in the 16-page *Laboratory Spotlight No. 21*, recently issued. Among the 50 items featured are the Beckman air comparison pycnometer, metal laboratory furniture, Precision Scientific wet test meters, International refrigerated centrifuges, and the Lourdes superspeed centrifuge.
The Harshaw Chemical Co. **6429**

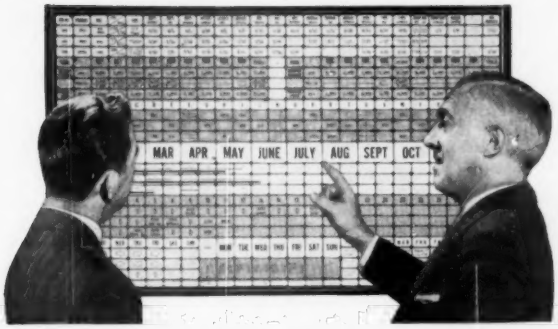
Temperature Monitor—New MSI *Bulletin 100* describes high-speed automatic monitor (HAM) system for scanning up to 3600 temperatues in 0.8 sec with reliability on the order of 50 million component unit hours mean time to failure.
Monitor Systems, Inc. **6430**

Reaction Apparatus—This new 8-page illustrated *Bulletin No. 4500* describes 1- and 2-liter bench-scale reactors with internal stirrer for pressures to 1000 psig and temperatures to 350 C. These are constructed of various corrosion-resistant metals and alloys suitable for numerous organic and inorganic chemical reactions. Internal cooling coils, glass liners, interchangeable heads, and other modifications are described.
Parr Instrument Co. **6431**

Torque Measuring—A new 12-page

(*Continued on page 432*)

You Get Things Done Better By Seeing What's Happening



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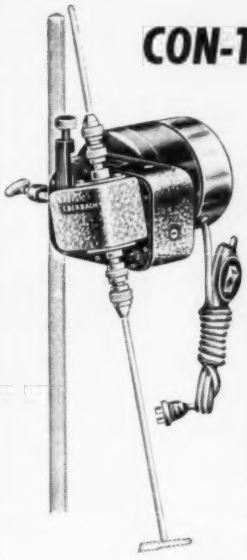

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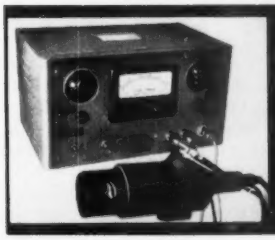

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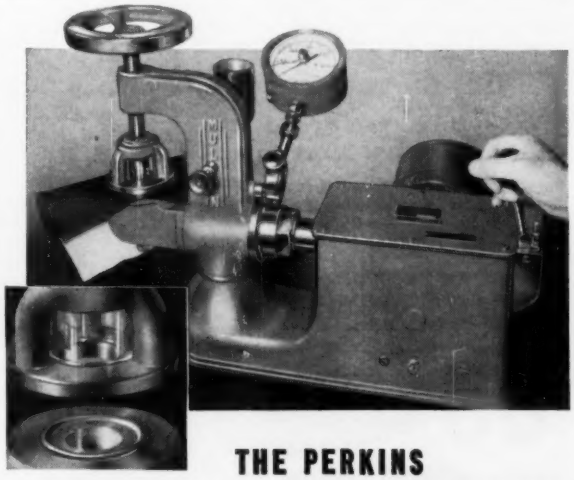

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NEW LITERATURE

(*Continued from page 430*)

brochure illustrates how to measure the torque characteristic and speed of motors, gear trains, servo mechanisms, and potentiometers. Covers torque ranges from $\frac{1}{4}$ gm-cm to 200 lb-in. Includes formulas for computing power and efficiency and methods of using stroboscopes and tachometers for analyzing rotating motion.
Power Instruments, Inc. 6432

LABORATORIES

Jarrell-Ash Co., Newtonville, Mass.—The Jarrell-Ash Company announces an expansion of its laboratory services. Well known for its services to industry and research in spectrochemical analysis, the laboratory has extended its services into the following fields: gas chromatography (organics and dissolved gases), X-ray diffraction, dissolved oxygen, and fluorometry (traces of beryllium and uranium).

MATERIALS

Clad Metals—*Bulletin Z-106*, a 2-page data bulletin, describing solder-clad metals for semiconductor and other applications, is now offered. The data bulletin lists overlay materials such as tin, tin-antimony, etc., along with base metals on which these are clad, including nickel, nickel-iron alloys, copper, gold, and silver.
Accurate Specialties Co., Inc., Hackensack, N. J.

Wear-Resistant Aluminum—A new 7-page engineering report describes hard-anodized coatings for imparting wear-resistance to aluminum alloys. The new coatings—as hard or harder than glass or hard-chromium plate—can be applied to practically all aluminum alloys as easily as conventional anodizing. Scratch hardness of the coating (Bierbaum method) runs from 3000 to 5000 from the center to the base of the film. Although surface finish of the applied coating is coarser than the original metal finish, it can be honed or polished to a low microinch finish with substantial improvement in wear resistance. The report details physical properties and results of complete hardness studies. It illustrates the effect of coating on part dimensions and gives specific cost figures.
Allen Aircraft Products, Inc., Ravenna, Ohio

Dry Lubricant—Typical extreme pressure applications of Molykote lubricating sticks are the subject of a *Data Sheet No. 128* recently published. According to the data sheet the lubricating stick, which contains molybdenum disulfide solid lubricant in a resin binder, is particularly useful on grinding wheels and cutting tools.
The Alpha-Molykote Corp.

Vycor Brand Glasses—The properties and advantages of Vycor brand glasses are given in a revised brochure recently published. Titled *Vycor Industrial Glassware*, the booklet also lists applications for the 96 per cent silica glasses. The newly illustrated *Catalog B-91* incorporates the latest data on the ten glasses from which Vycor brand products are made.
Corning Glass Works, Corning, N. Y.

Anti-Static Fluid—A new chemical fluid to prevent build-up of static charges on plastic-faced instruments has been introduced. Static electricity on meter and instrument windows deflects pointers, causes faulty readings, and attracts and holds air-borne dust and dirt. The new anti-static fluid provides a thin transparent coating which drains off static electricity.
Daystrom, Inc., Newark, N. J.

Silicon Rubber—A new family of self-bonding silicone rubber compounds and reinforced gums that afford a primerless bond to ferrous-containing metals stronger than the highest strength silicone rubber have been developed. Designated SE-5504U, the material is a high-strength, extreme-low-temperature compound similar to GE's standard SE-555. SE-5504U is a gray compound with a typical physical profile after cure of 25 hr per 350 F as follows: tensile strength, 1500 psi; tear, 200 psi; elongation, 550 per cent; durometer, 50; compression set 22 per 300 F, 45 per cent.
General Electric Co., Waterford, N. Y.

Anodized Foil—This anodized foil is available in gages from 0.002 to 0.040 in., in clear, black, and all standard colors, mat or polish finish, with or without adhesive backing, any width to 24 in. These foils are particularly desirable for decorative trim, nameplates, knob inserts, bezels, perforated metals, expanded metals, and for the stamping industry serving radio and TV manufacturers.
Girder Process, Inc., Hackensack, N. J.

Rubber—A hardy, new industrial rubber lining material that cold-bonds itself to metal and other surfaces with field-applied cement has been developed. The new material is designed to protect interior surfaces of chutes, mills, cyclone collectors, shot and sand blast machinery, and other equipment. It also is suitable for recapping conveyor belts.
The Goodyear Tire & Rubber Co., Akron, Ohio

Corrosion—Various kinds of corrosion and the different metals suited to resist them are given a thorough review in *Harper Corrosion Guide*, a 24-page illustrated brochure recently published. Written to help manufacturers build corrosion resistance into their products and properties, the guide analyzes the seven basic types of corrosion and shows what specific kinds of metals best resist them. These include brass, naval bronze, silicon bronze, nickel and high-nickel alloys, stainless steels, aluminum, copper, monel metals, and high-temperature alloys. A corrosion guide chart lists 136 types of corrosive agents that engineers and maintenance people may be troubled by and shows how well each of eight types of metals resists each of these agents.
The H. M. Harper Co., Morton Grove, Ill.

New Steel—A new 18 per cent nickel alloy steel with unmatched toughness at the highest strength levels of traditional alloy steels has been developed. This paves the way for a new family of high-strength "Mar-aged" steels with advanced engineering design possibilities for civilian and defense applications involving exceptionally high pressure and stress. It is the only known material which has the ability to achieve a yield strength in excess of 250,000 psi while maintaining a nil ductility temperature below −80 F. Another outstanding characteristic of 18 per cent nickel steel is its excellent notched tensile strength which exceeds 400,000 psi (measured under the most severe test conditions with a notch radius of 0.0005 in.). Tests have shown that this new alloy possesses a remarkable resistance to delayed cracking when exposed to a severe corrosive atmosphere in a highly stressed condition.

The International Nickel Co., Inc., New York, N. Y.

Steel — High - strength columbium-treated steels with added atmospheric corrosion resistance are being marketed. Addition of copper (0.20 minimum) to the columbium-treated grades, designated JLX-45-W, -50-W, -55-W and -60-W, provides a level of atmospheric corrosion resistance approximately twice that of mild carbon steel and equal to the level found in some of the high-strength, low-alloy proprietary grades. J&L columbium-treated steels have minimum yield properties for thees respective grade designations of 45,000, 50,000, 55,000, and 60,000 psi.

Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Porcelain Enamels—Porcelain enamels for steel with firing temperatures 500 F below conventional enamels is the subject of a new 4-page supplement to *Lead in the Ceramic Industries*. Because these new enamels fire at only 1000 to 1100 F, drastic reductions in furnace costs, maintenance, and fuel costs are possible. Low firing enamels can also expand product lines. The supplement gives full details on both these points.

Lead Industries Assn., New York, N. Y.

Missile Material—Continuing research and development on graphite cloth, a high-temperature material being extensively evaluated for missile components, has tripled the strength and doubled the flexibility, according to its manufacturer. Combined with phenolic resins to produce a high-pressure molding compound, graphite cloth has been tested in exit systems in the development of solid-fuel rocket engines. Modification of the complex processing techniques employed in converting organic fibers to essentially pure graphite has tripled the average breaking strength of graphite cloth and at the same time has doubled the flexibility.

National Carbon Co., New York, N. Y.

Abrasive—A much-improved high-hardness pearlitic malleable abrasive which gives 15 per cent faster cleaning action without decreasing abrasive life was announced. A new heat process which reduces graphitic carbon levels to less than 0.03 per cent of total content is reported to be responsible for the extended effectiveness of the product.

National Metal Abrasive Co., Cleveland, Ohio

Joint Filler—"Flexjoint," a chemically resistant joint filler with a high degree of load-bearing ability, bonds to both concrete and brick surfaces with strength greater than that of the materials it joints. Flexjoint is an expansion-contraction filler which remains flexible over a wide useful temperature range. It is a two-component resin system formulated in both a pouring grade and a caulking grade. The pouring grade cures rapidly into a stiff contraction-expansion joint material. The caulking grade can be used as a strongly bonded sealout, caulking material, or expansion joint for metal, concrete, stone, masonry, or wood.

Pennsalt Chemicals Corp., Natrona, Pa

NEW PLUS FOR PLASTIC

Plastic was once considered very sensitive to heat, but scientists have exposed a plastic missile nose cone to temperatures up to 20,000 F and recovered it intact.

Engineer as Space Age Man, by General James M. Gavin, Towne Lecture

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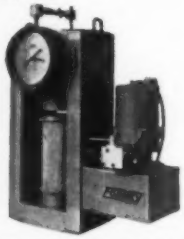

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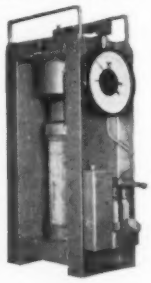

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OTS REPORTS

THESE REPORTS, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Office of Scientific Research and Development Microfilm Index, PB 161976, $8.
On Stress Interaction in Fatigue and a Cumulative Damage Rule, Part 2-7075, Aluminum Alloy, PB 161837, 75 cents.
The Effect of Neutron Irradiation on the Charpy-V and Drop-Weight Test Transition Temperatures of Various Steels and Weld Metals, PB 161448, 75 cents.
The Effect of Plastic Strain Rate on Diffusion in Aluminum-Zinc Alloys, PB 161884, $1.50.
The Effects of Inelastic Action on the Resistance to Various Types of Loads of Ductile Members made from Various Classes of Metals, PB 161836, $2.25.
A Mechanical Property Forecaster for Titanium Alloys, PB 161018, 50 cents.
Corrosion of Superalloys by Selected Fused Salts, PB 161848, $2.25.
Physical Properties of Some Nickel-Base Alloys, PB 151086, $2.75.
Strain Aging of Refractory Metals, PB 151092, $1.75.
Development of Methods and Instruments for Mechanical Evaluation of Refractory Materials at Very High Temperatures, PB 171012, $2.25.
The Viscosity of Liquid Metals (USSR), 60-21969, 50 cents.
Soviet Nonferrous Metallurgy No. 12, Selected Translations, 60-41166, $1.
Soviet Nonferrous Metallurgy No. 17, Selected Translations, 60-41680, 75 cents.
Analytic Investigation of the Processes in a Ferrite Core, 60-11793, 50 cents.
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Cylindrical Sandwich Construction Design, PB 161793, $4.
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Seventh Materials Review (principally in polymers and plastics), PB 161971, $2.50.
Commercial Standard for Schedule A Type I, and Schedule A Type II, Polyvinyl Chloride Pipe, TS-5523.
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Summary of Recommendations for Research and Development in Materials, PB 161865, $1.50.
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Research on New High-Temperature Semiconducting Materials, PB 161938, $3.
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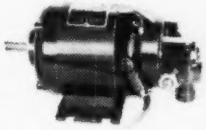

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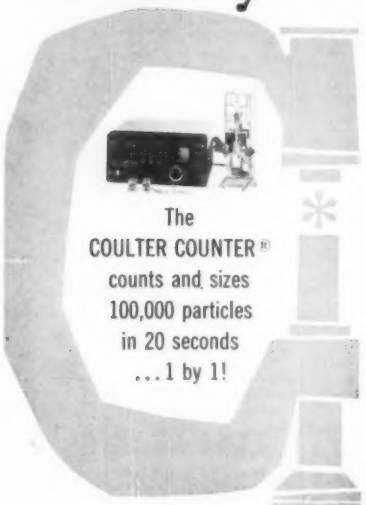

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NEW MEMBERS

The following 98 members were elected from March 10, 1961 to April 6, 1961 making the total membership 10,502 . . . Welcome to ASTM. Names are arranged alphabetically, company members first, then individuals. Your ASTM Year Book shows the areas covered by the respective Districts.

Central New York District

Graham, Malcolm D., principal civil engineer, New York State Department of Public Works, Albany, N. Y.

Chicago District

Dreyer, William N., works manager, Wisconsin Wire Works, Appleton, Wis.
Dube, Arun K., director, research and engineering Automation Alloys, Inc., Morocco, Ind. [A]*
Johnson, Robert E., laboratory supervisor, Whirlpool Corp., St. Paul, Minn.
Johnston, Lee G., manager of laboratories, American Institute of Laundering, Joliet, Ill.
Klima, Karel, research metallurgist, International Harvester Co., Chicago, Ill.
Kondner, Robert L., assistant professor of civil engineering, Northwestern University, Northwestern Technological Inst., Evanston, Ill. [A]
Larson, R. W., president, Larpen Industries, Inc., Milwaukee, Wis.
Liu, Hao Wen, research assistant professor, University of Illinois, Urbana, Ill.
Marks, Byron A., ensign, Civil Engineers Corps, U. S. Department of the Navy. [A]
Marta, Henry A., research engineer, Research and Development Laboratory, Square D Co., Park Ridge, Ill. [A]

*[A] denotes Associate Member.

Patrick, Robert L., president, Alpha R & D, Inc., Blue Island, Ill.
Steiner, Terry E., technical director of laboratory, Marathon Rubber Products Co., Wausau, Wis. [A]
Sturdevant, B. L., head of design group, Stanley Engineering Co., Muscatine, Iowa
Tiede, Milton G., manager, surfactants, Rath Chemicals Div., Rath Packing Co., Waterloo, Iowa
Ver Halen, R. T., engineer, Griffin Wheel Co., Bensenville, Ill.

Cleveland District

Standard Slag Co., The, T. G. Brown, sales manager, Youngstown, Ohio
Alexander, Claude H., manager, product improvement, B. F. Goodrich Chemical Co., Cleveland Ohio
Squires, William G., division engineer of test, Ohio State Department of Highways, Ravenna, Ohio.

Mississippi Valley District

McCracken, William W., materials engineer, The Bendix Corp., Kansas City, Mo.

New England District

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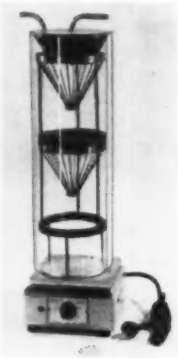

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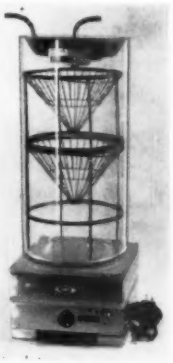

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Allen, Henry W., plant chemist, Dragon Cement Co., Division of American-Marietta Co., Thomaston, Me.
DiCorpo, Louis A., sales engineer, Brookfield Engineering Laboratories, Stoughton, Mass. [A]
Farkas, Emery, senior research chemist, Dewey & Almy Chemical Div., W. R. Grace and Co., Cambridge, Mass.
Hibel, Morton, product engineer, Transitron Electronic Corp., Wakefield, Mass. [A]
Macchi, A. John, A. J. Macchi, Engineers, Hartford, Conn.

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Municipal Testing Laboratory, Lawrence A. Farb, owner, Hicksville, N. Y.
Tube Reducing Corp., F. P. Huston, chief engineer, Wallington, N. J.
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Gaynes, Norman I., technical director, Titanine, Inc., Union, N. J.
Hamlin, Walter C., quality control manager, The Summit Finishing Co., Inc., Thomaston, Conn.
Stanberry, C. J., manager, Customer Service Laboratory, Continental Oil Co., New York, N. Y.
Wong, Han M., president, Dulon, Inc., Holbrook, N. Y.

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Coffey, Carleton T., Jr., survey branch, Engineering Div., U. S. Corps of Engineers, Department of the Army, San Francisco, Calif. [A]
Mitchell, James K., assistant professor of civil engineering, University of California, Berkeley, Calif.

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Butler, Sharon Lynn, associate engineer, Boeing Airplane Co., Seattle, Wash. [A]
Crawford, Robert J., laboratory director, Pope & Talbot, Inc., Portland, Ore. [A]
Mensah, Kwaku, metallographer, Tektronix, Inc., Portland, Ore. [A]

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Elms, Robert L., metallurgist, W. R. Meyers Co., Bedford, Inc.

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Calmon, C., director of laboratories, Ionac Chemical Co., A Division of Pfaudler Permutit, Inc., Birmingham, N. J.
Gienger, Edwin B., Jr., manager, polymer applications research and development, International Latex Corp., Chemical Div., Dover, Del.
Gregg, Harold I., mechanical engineer, J. E. Lonergan Co., Philadelphia, Pa.
Miller, Matthew G., Instrumental Analyses Dept., Food Machinery and Chemical Corp., Princeton, N. J.
Pennsylvania Turnpike Commission, Robert A. Farley, chief engineer, Harrisburg, Pa.
Slater, Morris N., engineering leader, Chemical and Physical Laboratory, Radio Corporation of America, Mountain Top, Pa.

Pittsburgh District

Dixon, L. A., assistant engineer of tests, The Pennsylvania Railroad Co., Test Dept., Altoona, Pa.
Kavoulakis, Alexander J., chief chemist, Pittsburgh Coke and Chemical Co., Neville Island, Pittsburgh, Pa.
Lohse, Robert M., Universal-Cyclops Steel Corp., Bridgeville, Pa.
Wray, Robert I., maintenance engineer, Kenneth Tator Associates, Coraopolis, Pa.

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(*Continued on page 438*)

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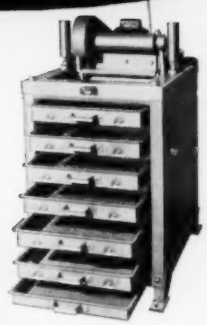

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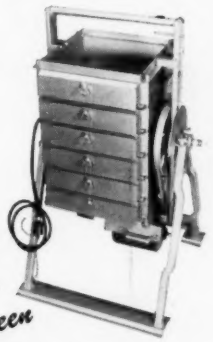

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Parise, Frank M., laboratory assistant, Penn-Dixie Cement Corp., Clinchfield, Ga. [A]
Schneider, Kenneth G., Jr., Specifications Dept., Taylor & Crabtree, Nashville, Tenn. [A]
U. S. Department of the Navy, Public Works Dept., Robert Q. Heglund, public works officer, U. S. Naval Station, Mayport, Fla.
Warren, Harry R., quality control manager, Technical Dept., Masonite Corp., Laurel, Miss.

Southern California District

Dress, Vern E., materials and processes engineer, Production Engineering Dept., Lockheed Aircraft Corp., Burbank, Calif.
Drury, Frederick W., Jr., general sales manager, Rodeffer Industries, Inc., Pasadena, Calif.
Garden Grove, City of, Charles R. Handy, director of public works and city engineer, Garden Grove, Calif.
Hood, Russell G., consulting geologist, Tujunga, Calif.
Schmidt, C. William, vice-president, Hood & Schmidt, Inc., Burbank, Calif.
Simpson, David, quality control manager, Electralab Printed Electronics Corp., Encinitas, Calif.

Southwest District

Western Electric Co., Inc., Oklahoma City Works, L. B. Rosendahl, department chief, engineering, Oklahoma City, Okla.
Hunt, J. E., soils engineer, Texas Highway Dept., Materials and Tests Div., Camp Hubbard, Austin, Tex.
Kellogg, K. B., chief chemist, Ormet Corp., Burnside, La.
Rogers, James A., southwest manager, Pacific Scientific Co., Arlington, Tex.
Thompson, J. Neils, professor of civil engineering and director, Balcones Research Center, University of Texas, Austin, Tex.
Welch, Robert Carlton, instructor of civil engineering, University of Texas, Austin, Tex. [A]

Washington, D. C., District

Arveson, Clarence H., specialist, timber products, Rural Electrification Administration, Washington, D. C.
Blake, Howard C., III, packaging technologist, Reed Research, Inc., Washington, D. C. [A]
Federal Housing Administration Library, O. S. Kolmer, director, General Services Div., Washington, D. C.
Miracle, John Ernest, research associate, Cement and Concrete Reference Laboratory, National Bureau of Standards, Washington, D. C.
Taylor, Lewis B., Jr., structural engineer, Developmental Engineering Corp., Leesburg, Va.

Western New York–Ontario District

Montegani, A. L., engineering supervisor, CLM Industries, Station H, Toronto, Ont., Canada

Outside Established Districts

Blossom, Gordon E., estimating engineer and superintendent, Robertson & Cave, Inc., Great Falls, Mont.
Nottingham, Dennis, designer, State of Montana, Highways Dept., Helena, Mont. [A]
Tateishi, Herbert T., testing engineer, State Department of Transportation, Honolulu, Hawaii.

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Braive, Charles, engineer, Liege, Belgium.
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Goodbrand, Eric C., managing director, Goodbrand and Co., Ltd., Britannia Foundry, Stalybridge, Cheshire, England.
Haenni, Raoul, plant manager, Societe des Elastomores de Synthane, Berre L'Etang, France.
Hall, Graham, deputy general superintendent, Electrolytic Zinc Company of Australasia, Ltd., Hobart, Tasmania.
Humphreys, R. D., refinery manager, Canadian Oil Cos., Ltd., Innisfail, Alta., Canada.
Kozicki, Peter, Alberta branch manager, B. B. Torchinsky and Associates, Saskatoon, Sask, Canada. [A]
Lechler, George P., Jr., manager, Jamaica Engineering and Research Co., Ltd., Kingston, Jamaica, B. W. I.
Locatelli, Giuseppe, engineer, Milan, Italy.
Malhotra, Prannath, professor and head, Mechanical Engineering Dept., G. S. Technological Inst., Indore (M.P.), India.
Mosle, Huter-Georg, chemist, Siemems-Electrogerate A. G., Berlin-Gartenfeld, Germany.
Reed, Rowland Ivor, Chemistry Dept., The University, Glasgow, Scotland.
Sjostrom, Sverker, technical director, A.-B. Scania-Vabis, Sodertalje, Sweden.
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ATLAS ELECTRIC DEVICES CO. 416

BUEHLER LTD. 423
BURRELL CORP. 417

COMPUDYNE CORP. 426
COULTER ELECTRONICS, INC. 436
CUSTOM SCIENTIFIC INSTRUMENTS, INC. 418

DETROIT TESTING MACHINE CO. 437
DILLON & CO., INC., W. C. 427, 439

EASTMAN KODAK CO. 413
EBERBACH CORP. 431

FISHER SCIENTIFIC CO. 425
FORNEY'S, INC.
TESTER DIV. 434

GENERAL RADIO CO. ..... IBC
GILSON SCREEN CO. 437
GRAPHIC SYSTEMS 431

HELLER CO., GERALD K. 435
HEVI-DUTY ELECTRIC CO.
DIVISION OF BASIC PRODUCTS CORP. 421
HIGH VOLTAGE ENGINEERING CORP. 355
HIRSCHMANN CO., INC., CARL 419
HOGGSON & PETTIS MFG. CO. 427
HUNTER SPRING CO.
A DIVISION OF AMERICAN MACHINE AND METALS, INC. 429

INSTRON ENGINEERING CORP. ..... IFC
INSTRUMENTS FOR RESEARCH AND INDUSTRY 428
INSTRUMENT SOCIETY OF AMERICA 415

KLETT MFG. CO. 435

MASON INSTRUMENT CO., INC. 431

OLSEN TESTING MACHINE CO., TINIUS ..... OBC
OZONE RESEARCH AND EQUIPMENT CORP. 422

PARR INSTRUMENT CO. 429
PERKINS & SON, INC., B. F. 431
PICKER X-RAY CORP. 432, 433
PLAS-TECH EQUIPMENT CORP. 358

SARGENT & CO., E. H. 354
SCOTT TESTERS, INC. 430
SIEBURG INDUSTRIES INC. 439
SYNTRON CO. 420

TAGLIABUE DIV., MARSHALLTOWN MFG., INC. 438
TESTING MACHINES INC. 424
TESTLAB CORP. 436
THWING-ALBERT INSTRUMENT CO. 429

UNIT PROCESS ASSEMBLIES, INC. 438
UNITRON INSTRUMENT CO.
MICROSCOPIC SALES DIV. 440

WIEDEMANN MACHINE CO. 356

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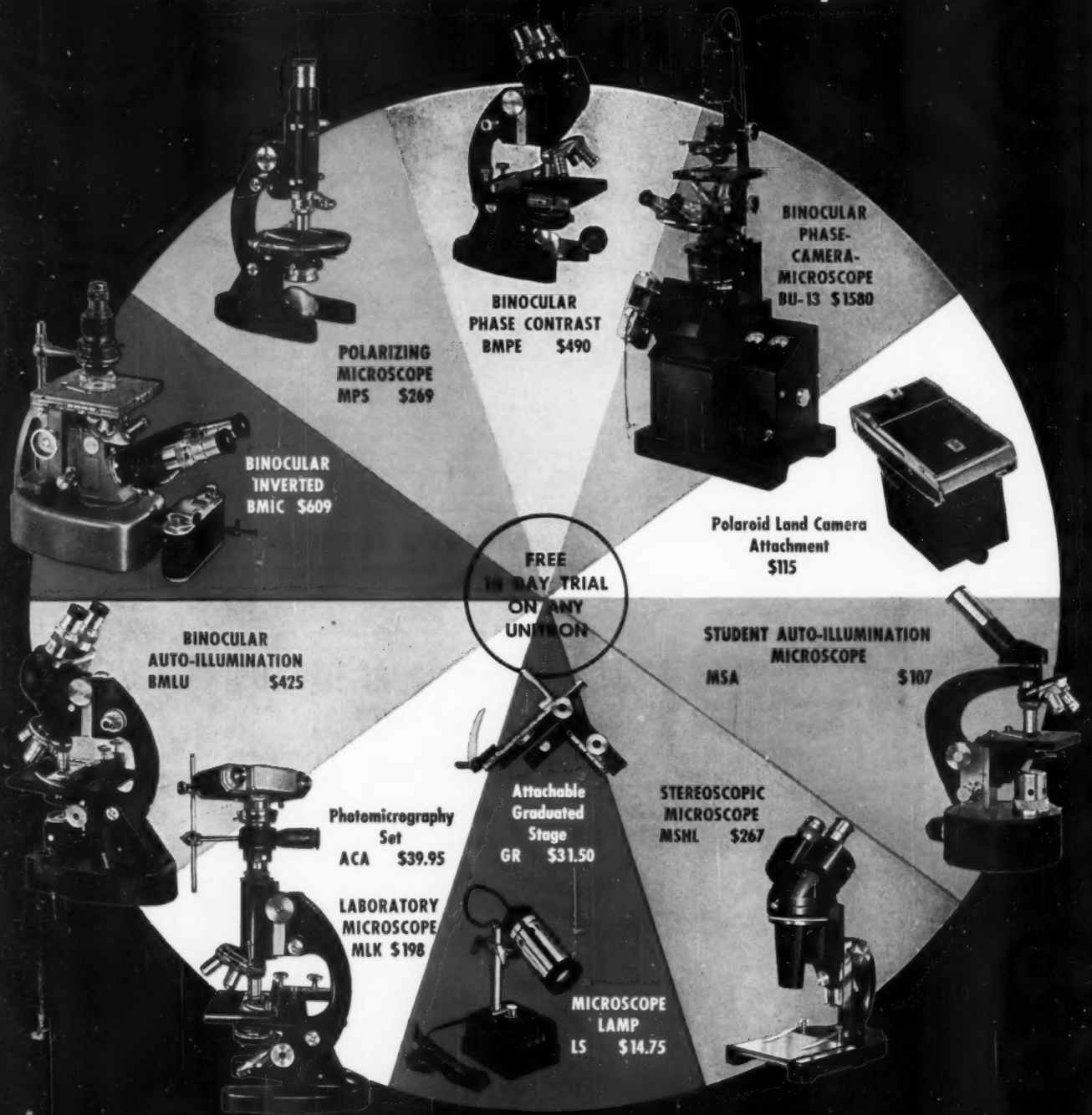
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